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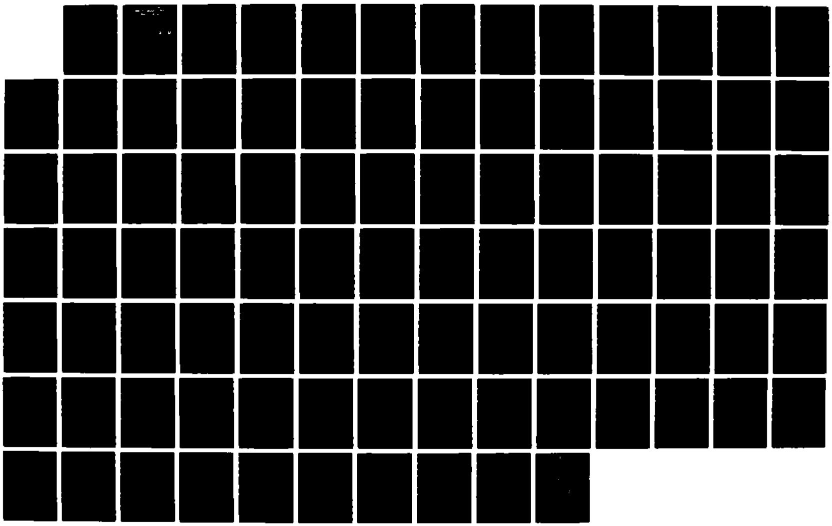

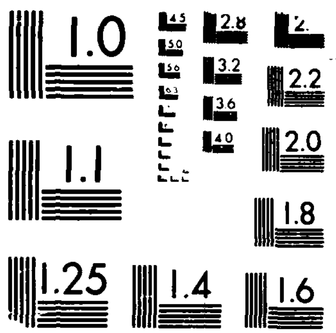

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NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

EFEECTS OF CHARGE DISTRIBUTION
WITHIN A PARTICLE BEAM
ON THE SUB-CERENKOV RADIATION

by

Jung, Yun Su
December 1987

Thesis Advisor: John R. Neighbours

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The charge distribution of periodic electron beam pulses generates patterns of sub-Cerenkov radiation distinctive of the distribution of charge with in a bunch. Mapping the radiation pattern from different charge shapes may provide insight into whether charge pulse shapes can be determined from observed radiation patterns. The radiation patterns of Gaussian, Level, and Trapezoidal function were mapped by computer simulation. Near 90° to the beam, the radiation patterns of all three charge distributions developed an envelope proportional to the fourier transform of the charge bunch distribution when the wavelength of the emitted radiation was comparable to the size of the bunch. For the Gaussian function, the envelope is Gaussian, for the level function it is a sinc function. Since the envelope for the trapezoidal function in the product of two sinc functions it is more difficult to analyze This work may provide a basis for determining the charge shape of electron beam pulses from the sub-Cerenkov radiation based on the radiation intensity pattern. Keywords: /

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Effects of Charge Distribution within a Particle Beam on the sub–Cerenkov Radiation

by

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B.S., Republic of Korea Military Academy, 1974

Submitted in partial fulfillment of the
requirements for the degree of

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from the

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ABSTRACT

The charge distribution of periodic electron beam pulses generates patterns of sub–Cerenkov radiation distinctive of the distribution of charge with in a bunch. Mapping the radiation pattern from different charge shapes may provide insight into whether charge pulse shapes can be determined from observed radiation patterns. The radiation patterns of Gaussian, Level, and Trapezoidal function were mapped by computer simulation Near 90° to the beam, the radiation patterns of all three charge distributions developed an envelope proportional to the fourier transform of the charge bunch distribution when the wavelength of the emitted radiation was comparable to the size of the bunch. For the Gaussian function, the envelope is Gaussian, for the level function it is a sinc function. Since the envelope for the trapezoidal function in the product of two sinc functions it is more difficult to analyze. This work may provide a basis for determining the charge shape of electron beam pulses from the sub–Cerenkov radiation based on the radiation intensity pattern.

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I. INTRODUCTION

A. HISTORY

A very faint emission of bluish–white light, what was later–on called Cerenkov radiation, from transparent substances placed nearby a radioactive sources had been observed by Mme Curie in 1910 . Although electromagnetic theory had been sufficiently developed at that time to describe this phenomenon, the first deliberate attempt to study the phenomenon was made by Mallet after many years, who found that the light emitted from a wide variety of transparent bodies placed close to radioactive source always had the same bluish–white light quality, and that spectrum was continuous, not possessing the line or band structure characteristic of fluorescence [Ref. 1: p. 1].

P.A. Cerenkov carried out a series of experiments between 1934 and 1938 related to the phenomenon. In 1937 Ilya Frank and Igor Tamm proposed a satisfactory theory of the radiation. The experimental results and theoretical predictions were in excellent agreement. A complete description of Cerenkov radiation, as well as exact mathematical treatment is given in [Ref. 1: p. 1].

B. WHAT IS THE CERENKOV RADIATION ?

A charged particle or a group of charged particles moving through a medium at a speed greater than the (phase) velocity of light in the same medium will generate a continuous spectrum of electromagnetic radiation. This process is referred to as Cerenkov radiation.[Ref. 2: p.9]

C. PREVIOUS RESEARCH AT N.P.S.

The research on Cerenkov radiation has been conducted by Professors Fred R. Buskirk, John R. Neighbours and others in the Naval Postgraduate school since the LINAC was established. Recent work has concentrated on the determination of electron beam bunch profile through Cerenkov radiation.

The work was aimed to illustrate examples of the consequences of the finite spatial charge distribution to show that Cerenkov radiation emitted at low microwave frequencies may be used to characterize the properties of an intense relativistic beam in air. The results were that the spatial charge distribution of an electron pulse, along with the beam interaction length, determines the Cerenkov radiation distribution as a function of frequency. An angular distribution of the Cerenkov radiation can, in principle, measure its spatial charge distribution.[Ref. 3:p. 1994].

D. PURPOSE

The charge distribution of a bunch influences the pattern of radiation produced. Detailed calculations for several simple charge distributions have been carried out for the Cerenkov case [Ref. 4:pp. 1994,1996]. The object of this work is to assess the effect of the charge distribution of a bunch on the sub–Cerenkov radiation from a charged particle beam. Specifically, this means investigation of the short beam path region at energies below the threshold.

II. THEORY

A. BACKGROUND

A fast, charged particle may cause electromagnetic radiation in a dielectric medium when it moves with a constant speed. Suppose an electron to be moving relatively slowly through a transparent medium as shown on Fig.1.1 a). As the particle passes through the medium, each elemental region of the medium along the track will in turn receive a very brief electromagnetic pulse and be polarized, producing a dipole. An electromagnetic pulse is generated by the formation and disappearance of the dipole as the bunch passes. The electromagnetic pulse propagates away from the dipole source at the velocity of light in the medium. The distance between wave fronts is compressed as the velocity of the electron bunch increases. This effect is similar to the doppler effect for sound radiated from a moving source. If the speed of the particle is less than the propagation velocity in the medium, the electromagnetic field produced is called sub–Cerenkov radiation. [Ref. 1: pp. 3–4]

If the electron is moving faster than light in the medium (see Fig 1.1 b), the the pulse source velocity is greater than that of the propagating electromagnetic wave which transport the energy. The result is a wavefront and where the emanated wavelets bunch together in phase. This shockfront of electromagnetic radiation is Cerenkov radiation. [Ref. 1: pp. 4–5]

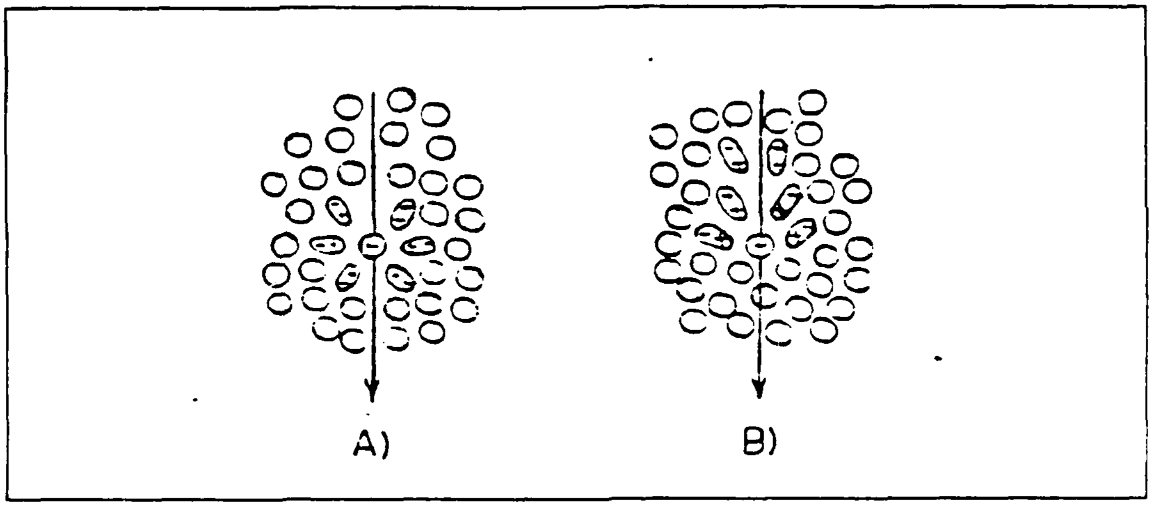


Fig. 2.1 Polarized Atoms in a Dielectric.

B. CHARACTERISTICS OF CERENKOV RADIATION

Fig. 2.2 shows the resultant Cerenkov radiation plane wavefront BC from particles traveling from A to B. Wavelets from point 0 to 5 are coherent along wavefront BC. The angle θ_c is given by the "Cerenkov relation":

$$\cos \theta_c = 1 / \beta n, \tag{2.1}$$

where n is the refractive index of the medium and β is the ratio of the velocity of the particle to the velocity of light in a vacuum [Ref. 1: pp.4–5].

From the above, the following is seen that:

(1) For medium of given refractive index n, there is a threshold velocity $\beta_{min} = (1/n)$, below which no radiation take place [Ref. 1: p. 5].

(2) For ultra-relativistic particles, for which $\beta \cong 1$, there is a maximum angle of emission, given by $\theta_{max} = \cos^{-1}(1/n)$.

(3) Radiation occurs mainly in the visible and near visible region for

which n > 1. In the X-ray region, above atomic resonances, n is usually less than 1; therefore Cerenkov radiation in the X-ray region is not probable [Ref. 3: p. 3252, Ref. 1: p. 6].

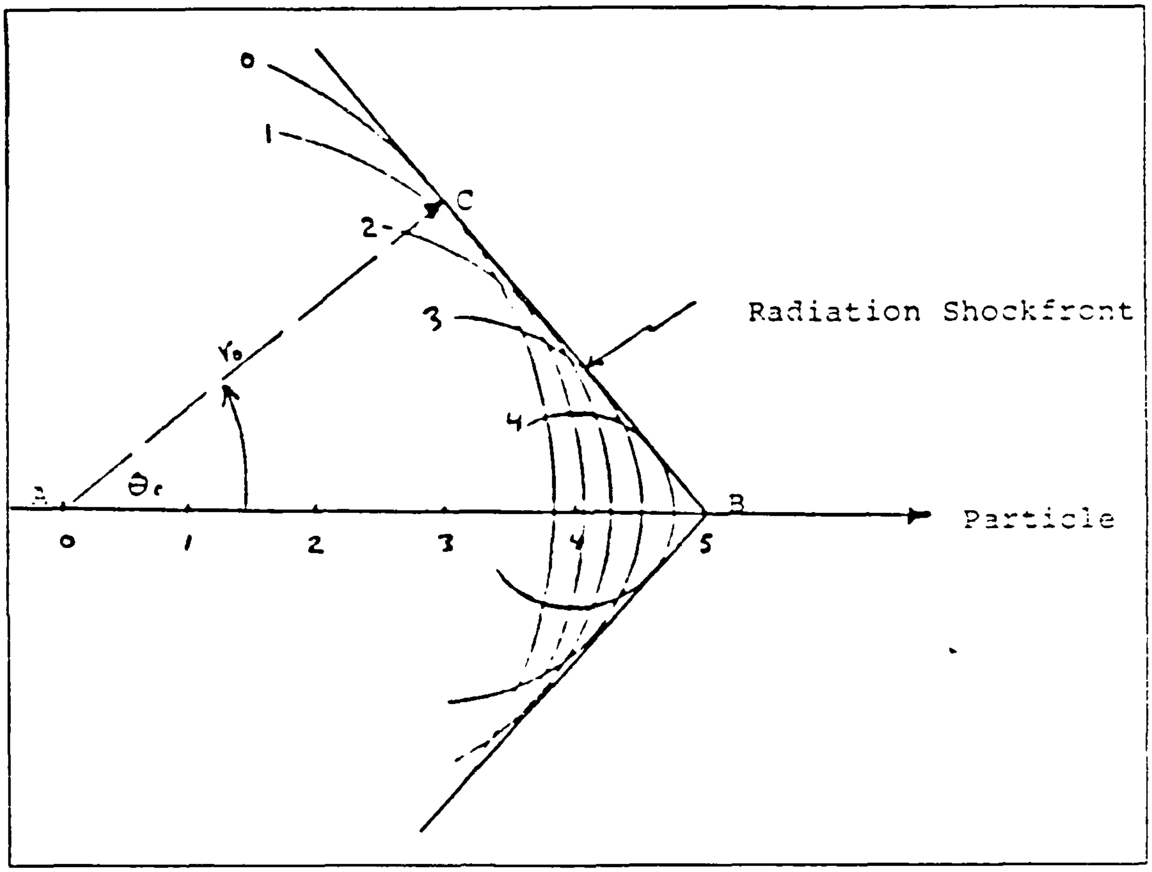


Fig. 2.2 Radiation Shockfront

(4) In a gas, θ_c has only a slight dependence on electron velocity because β must be close to one in order to obtain the Cerenkov condition [Ref. 3: p. 3249].

From the nature of the radiation, which has been described above, it may be

concluded:

(5) Azimuthal symmetry of the radiation produces a cone of radiation.

(6) The distribution in θ of the radiation intensity approximate a Dirac δ–function centered about Cerenkov angle 'θ_c'.

(7) Length AB in Fig.2 must be much larger than the radiated wavelength in order to avoid diffraction effects. For a finite radiation length, the diffraction effect is significant.

C. CALCULATED POWER OF COHERENT CERENKOV RADIATION

The total coherent power per unit solid angle, radiated at the frequency ν by a periodic charged particle beam in traveling a finite distance L at constant velocity is

$$W(\nu,\mathbf{k}) = \nu_0^2 \, Q \, R^2, \qquad (2.2)$$

where ν_0 is the fundamental frequency of the beam generator and ν is a harmonic of ν_0, q is the charge of an individual bunch, Q is a constant and R is the radiation function. The bunches in the beam are assumed to be unchanging in shape and size as the beam travels through the medium (usually air) at a velocity given by $\nu = \beta\, c_0$. The velocity of light in vacuum is c_0 and the velocity of light in the medium is $c = c_0/n$ where n is the index of refraction. The parameters used to describe the radiation are

$$Q = \mu c q^2/8\pi^2, \qquad (2.3)$$

which is a constant, where μ is the permeability of the medium, and the radiation function R is given by

$$R = 2\pi\eta \sin\theta \, I(u)F(\mathbf{k}), \tag{2.4}$$

where θ is the angle between the direction of travel of the charged particle beam and the direction of propagation of the emitted radiation, I(u) is the diffraction function, and F(**k**) is the form factor. [Ref. 5: pp.2741,2742]

The wave vector of the emitted radiation is **k** ($k = \omega/c$), and F(**k**) is the dimensionless form factor. That is, if $\rho(\mathbf{r})$ is the charge distribution of a single bunch, then the Fourier components of the charge are

$$\rho(\mathbf{k}) = \int \int_{-\infty}^{\infty} \int \rho(\mathbf{r}) e^{i\mathbf{k}\cdot\mathbf{r}} d^3r, \tag{2.5}$$

and the form factor is defined by

$$\rho(\mathbf{k}) = qF(\mathbf{k}). \tag{2.6}$$

For a point charge, F(**k**) is identically one for all values of **k**.
The dimensionless beam length parameter η which is defined as the ratio of the path length of the charged particle beam to the wavelength in the medium of the emitted radiation, appears in the radiation function explicitly, and implicitly as part of the diffraction parameter defined below:

$$\eta = L / \lambda. \tag{2.7}$$

The diffraction function is

$$I(u) = \sin u/u, \tag{2.8}$$

where the dimensionless diffraction parameter u depends upon the Cerenkov angle given by $\cos \theta_C = (n\beta)^{-1}$, as well as upon the beam length parameter and the radiation emission angle:

$$u -- \pi \eta [(n\beta)^{-1} - \cos \theta]. \tag{2.9}$$

The parameter η determines the periodicity of the diffraction pattern and also determines its magnitude. Since R depends directly upon η, the strength of the radiation is proportional to the square of the path length of the beam. [Ref. 5: pp. 2741,2742]

D. FINITE–LENGTH PATH

If the emission region has finite length, which may be realized by passing the electron beam through a gas cell, the radiation propagation direction is not confined to a sharp Cerenkov angle θ_C, but is spread over a range of emission angles. For the case of gas, for which the ordinary Cerenkov angle is a few degrees, the broadening is asymmetric about the Cerenkov cone, and the radiated power displays various interference lobes. This spreading effect depends only on the path length in the gas and does not depend on the electron bunch structure or periodicity of the bunches. [Ref. 3: pp. 3246,3251]

Radiation from the polarized molecules along the path of the electron beam is formally equivalent to diffraction from a single slit at angles far from normal incidence. The shift in the radiation peak can be understood as a

diffraction effect arising from the linearly varying phase of the radiation along the beam interaction length [Ref. 3: p. 3246].

Considerable power (about half in the case of a gas) appears outside the main lobe, and the latter is the peaked at angles much larger than the Cerenkov angle. The Cerenkov power radiated per unit path length is increased by large factors approaching 2 orders of magnitude for a gas path of finite length compared to one of infinite length [Ref. 3: p. 3251].

This increase in power is associated with the finite length of the radiating medium only. The effect should be approximately the same for either single or periodic electron bunches and should occur whether the bunches are effectively point charges or have significant size.

The value of the parameter u is affected by η and the beam energy through β. As either of these parameters is varied, the angular position of the zeros of I(u) changes. The emission threshold is defined as the situation when the first zero of the diffraction function enters the physical range. Applying this criterion, the result is that for small values of η, a Cerenkov–like radiation pattern is produced even when the product $n\beta < 1$. That is, the threshold occurs for $n\beta < 1$ at small values of η. As η increases (at constant $n\beta < 1$), the threshold is crossed and the radiation pattern becomes more chaotic. A full discussion of these geometrical effects is given in Ref. 5.

E. PERIODIC ELECTRON BUNCHES

Cerenkov radiation was considered for periodic bunches of electrons such as would be emitted by a typical traveling–wave electron linear accelerator (LINAC). Because the distribution of intensity of Cerenkov is proportional to the frequency, the radiation at microwave frequencies would be low unless

beams are intense and bunched so that coherent radiation by many electrons contributes [Ref. 2: p. 1531].

Periodic bunches of electrons produce Cerenkov radiation at harmonics of the bunch frequency, while a single bunch will radiate with a continuous frequency distribution. The effect of bunch size is reflected in the factor of the Fourier transform of the charge in the bunch, which causes the radiation to fall off at high frequencies, while at low frequencies all charges in the bunch radiate in phase.

At low frequencies such that the wavelength of the emitted radiation is of the order of the bunch size, the electrons in the bunch radiate coherently. This leads to large enhancement factors for typical bunches consisting of 10^8 electrons, and in fact allows the radiation to be significant at microwave frequencies. [Ref. 3: p. 3246]

At higher frequencies or harmonics, destructive interference, described by the Fourier transform of the charge density,decreases intensities with increasing frequency, until incoherent radiation takes over when the wavelength of the radiation is much less than electron spacing [Ref. 3: p. 3246].

When a single electron passes through a dielectric medium where a spatially periodic term is added to the dielectric constant, the result is radiation occurring even for electrons which do not exceed the velocity of light in the medium and at angles other than the Cerenkov cone angle. The non–Cerenkov part of the radiation is attributed to transition radiation. If the electron velocity were lower so that v/c were close to but less than unity, the peak in I would be pushed to the left toward 0° of θ such that $\cos\,\theta_c = v/c$ would be larger than 1. But the tails of the diffraction function I could extend

into the physical range $1 \leqq \cos\theta \leqq -1$, and this would be called transition radiation and be ascribed to the passage of the electrons through the boundaries of the gas cell. [Ref. 2: p. 1535]

F. PROFILE DETERMINATION OF A ELECTRON BEAM BUNCH

1. Effect of The Form Factor

The bunch form factors are Fourier Transforms $F(\mathbf{k})$ which differ depending on the charge distribution within a bunch. The form factor is identically one for a point charge, and for a finite charge distribution $F(\mathbf{k}) = 1$ for $\mathbf{k} = 0$. If all the charge within a bunch is of the same sign $F(\mathbf{k})$ must fall off as a function of k near the origin. Here we consider only line charge distribution and consequently the form factors are functions of the product of $k_z = k\cos\theta$ and appropriate lengths which are characteristic of the charge distribution of a bunch.

Thus the behavior of the form factor F over the range of emission angles is dependant on the ratio of the charge bunch lengths to the wavelength of the emitted radiation. For a small value of these ratios, the value of F is essentially unity for all angles. Then the emitted radiation pattern is modulated only by the geometrical envelope function as described in Ref. 5.

However for larger values of the ratios, the value of F over the range of emission angles can be significantly less than one. In this case the dependence of the form factor on angle is dramatic since the cosine term goes to zero at ninety degrees causing a form factor of unity. If, at same time the emission length ratio is small, a condition could be achieved where the majority of the Cerenkov power is radiated in a direction normal to the electron beam path.

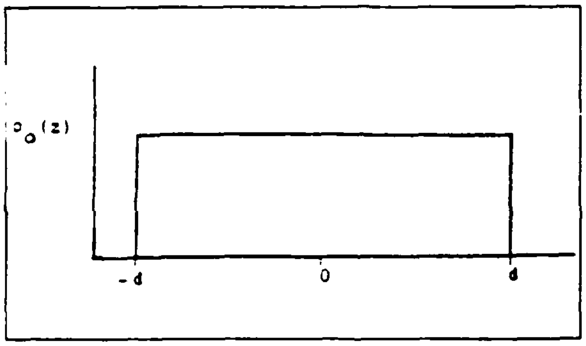
A complete angular map of Cerenkov radiation patterns may be used to characterize the properties of relativistic beam pulses, and may enable one to determine the beam pulse charge distribution from measured radiated patterns [Ref. 4: p. 1996].

2 Bunch Shapes and Corresponding Form Factors

Figure 2.3 diagrams the beam pulse shapes and presents the corresponding form factor expressions. [Ref. 8: pp. 16,17]

Level function

(a)

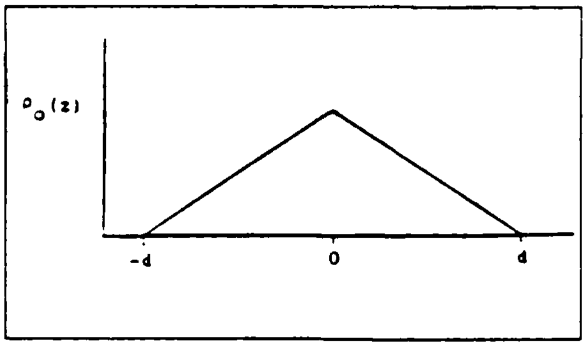


$$F(k_z) = \frac{\sin k_z d}{k_z d}$$

Figure 2.3 Electron Beam Charge Bunch Shapes and Corresponding Form Factors.

Triangular function.

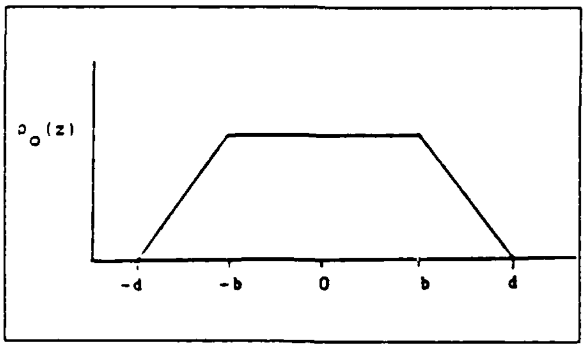
(b)



$$F(k_z) = Ad \left[\frac{\sin \frac{k_z d}{2}}{\frac{k_z d}{2}} \right]^2$$

Trapezoidal function

(c)



$$F(k_z) = AL \left[\frac{\sin \frac{k_z \ell}{2}}{\frac{k_z \ell}{2}} \times \frac{\sin \frac{k_z l}{2}}{\frac{k_z l}{2}} \right]$$

where $\ell = (l_t + l_b)/2$, $l = (l_b - l_t)/2$,

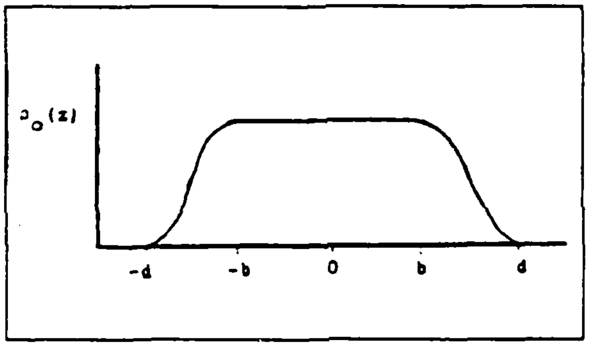
l_t = top level length of trapezoidal.

l_b = bottom level length of trapezoidal.

Figure 2.3 (cont.) Electron Beam Charge Bunch Shapes and Corresponding Form Factors.

Rounded function

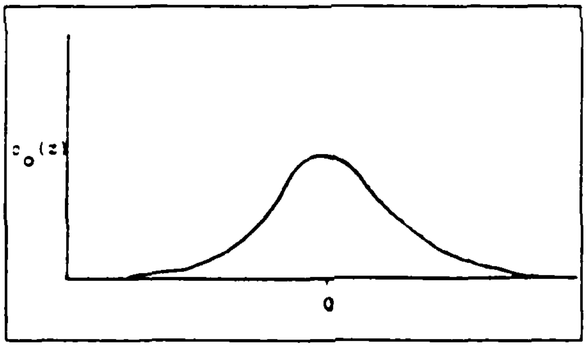
(d)



$$F(k_z) = \frac{8}{k_z^3(b+d)(d-b)^2}\left[2\sin\frac{k_z}{2}(d+b) - \sin k_z b - \sin k_z d\right]$$

Gaussian function

(e)

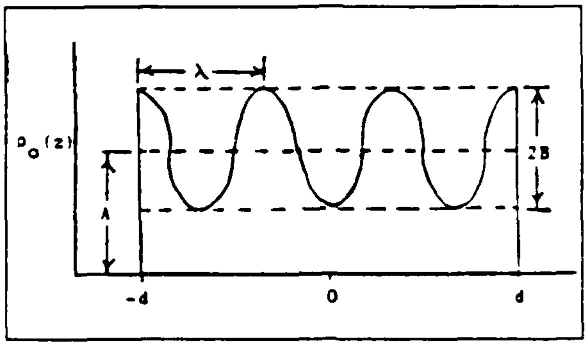


$$F(k_z) = e^{-\left[\frac{k_z b}{2}\right]^2} \quad \text{where } b = \text{bunch size.}$$

Figure 2.3 (cont.) Electron Beam Charge Bunch Shapes and Corresponding Form Factors.

Level Plus Ripple function

(f)

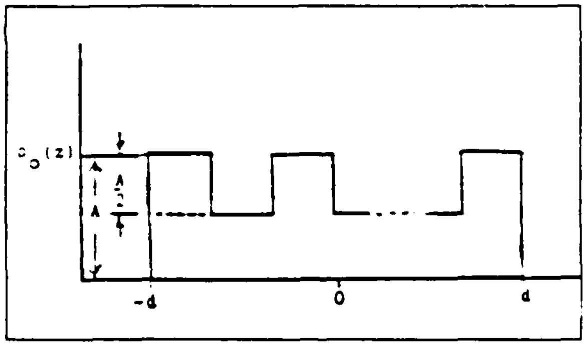


$$F(k_z) = \frac{\sin k_z d}{k_z d} + \frac{R}{2}\left[\frac{\sin(k_z + k_0)d}{(k_z - k_0)d} + \frac{\sin(k_z + k_0)d}{(k_z + k_0)d}\right]$$

where $R = B/A$ $\qquad k_0 = 2\pi/\lambda$

Multiple Hump function

(g)



$$F(k_z) = \frac{2\sin k_z d}{k_z d} - \frac{\sin k_z d\left[\frac{2N-3}{2N-1}\right]}{k_z}\Bigg|_{N=2} + \frac{\sin k_z d\left[\frac{2N-5}{2N-1}\right]}{k_z d}\Bigg|_{N=3}$$

where N = number of humps.

Figure 2.3 (cont.) Electron Beam Charge Bunch Shapes and Corresponding Form Factors.

III. CALCULATION AND RESULTS

A. PARAMETERS FOR CALCULATION

Professor J. R. Neighbours and others of the Department of Physics. Naval Postgraduate School, Monterey, California, developed a computer program to calculate and plot angular maps of the radiated energy per unit solid angle for a given form factor. The program originally was designed to run on a Tektronix Computer and considered the following one dimensional (i.e. in Z only) beam charge distributions: Gaussian, level (i.e. boxcar),level plus a sinusoidal, ripple combination,and a double hump.

This work was aimed to modify the program to run on the IBM 370 mainframe computer and plot the calculated power per solid angle, radiated at the frequency ν, using the DISSPLA V10.5. The results are limited to the three form factors for the rectangular, Gaussian and trapezoidal charge distributions. Calculations for other charge distributions are left for future work.

To calculate the total coherent power per unit solid angle, radiated at the frequency ν by a periodic charged particle beam in traveling a finite distance L at constant velocity, a set of parameters were chosen close to those available in an experiment.

(1) Index of refraction, $n = 1.000268$.

(2) Speed of light in vacuum, $c_0 = 2.997925 \times 10^8$ m.

(3) Fundamental frequency, $\nu_0 = 2.85$ GHz.

(4) Bunch charge, $B = 1.5 \times 10^{-12}$ Coulomb.

These values give an $n\beta$ product of $n\beta$ = 0.98, which is 2 % below the infinite path length threshold value of unity. By choosing different radiation harmonics and varying the path length the radiation pattern above (η = 12) and below (η = 37) the threshold for 2.555 Mev electron bunches, could be investigated. The calculations were carried out at constant η for the various charge distribution as the size of the distribution was varied.

B. GAUSSIAN FUNCTION

Fig. 3.1 through Fig. 3.8 show the radiation intensity pattern of Gaussian line charge distributions in sub–Cerenkov radiation ($n\beta$ = 0.98) for two different value of η. Fig. 3.1 through Fig. 3.4 are the results of using η = 12, with N = 3, varying the bunch length from 0.24 cm to 2.4 cm. The rest of them are for the case of using η = 37, and likewise, varying the bunch length. BL is the symbol used for bunchlength.

Figures 3.1–3.4 show the effect on the emitted radiation pattern as the bunch length is increased while the beam path parameter η is held constant at η = 12. With a bunch length of 0.24 cm the radiation pattern is essentially that of a periodic set of point charges. As the bunch length increases, a hump first becomes evident in Fig. 3.2 when the wavelength of the emitted radiation begins to become comparable to the size of the bunch. Further increase in bunch size shows an increasing dominance of the form factor until finally the radiation pattern is almost completely dependant on the form factor. In Fig. 3.4 the envelope of the radiation pattern is the form factor for the Gaussian charge distribution except for a slight skewing caused by the geometrical envelope function.

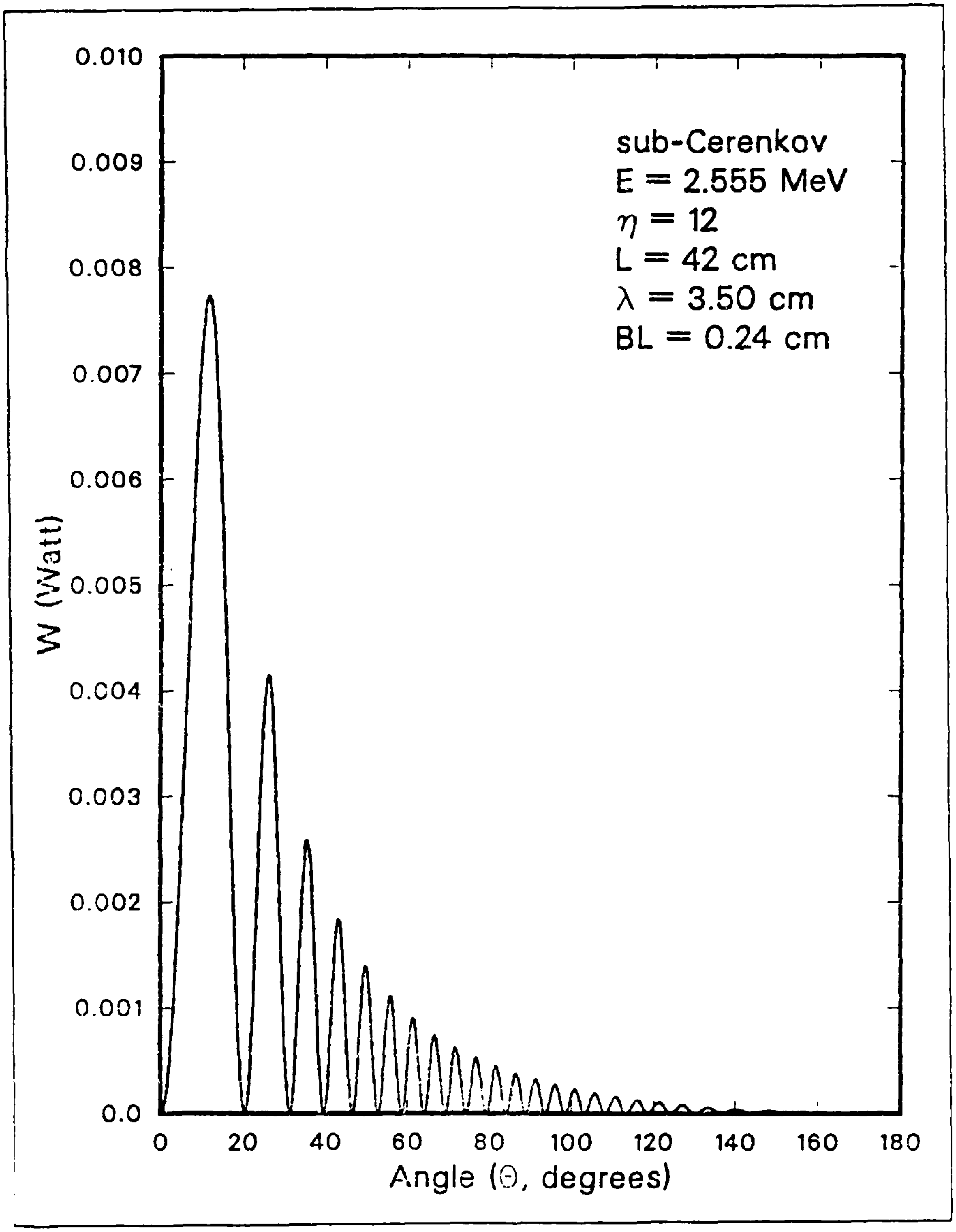


Fig. 3.1 Gaussian Function with $BL/\lambda = 0.069$, $\eta = 12$

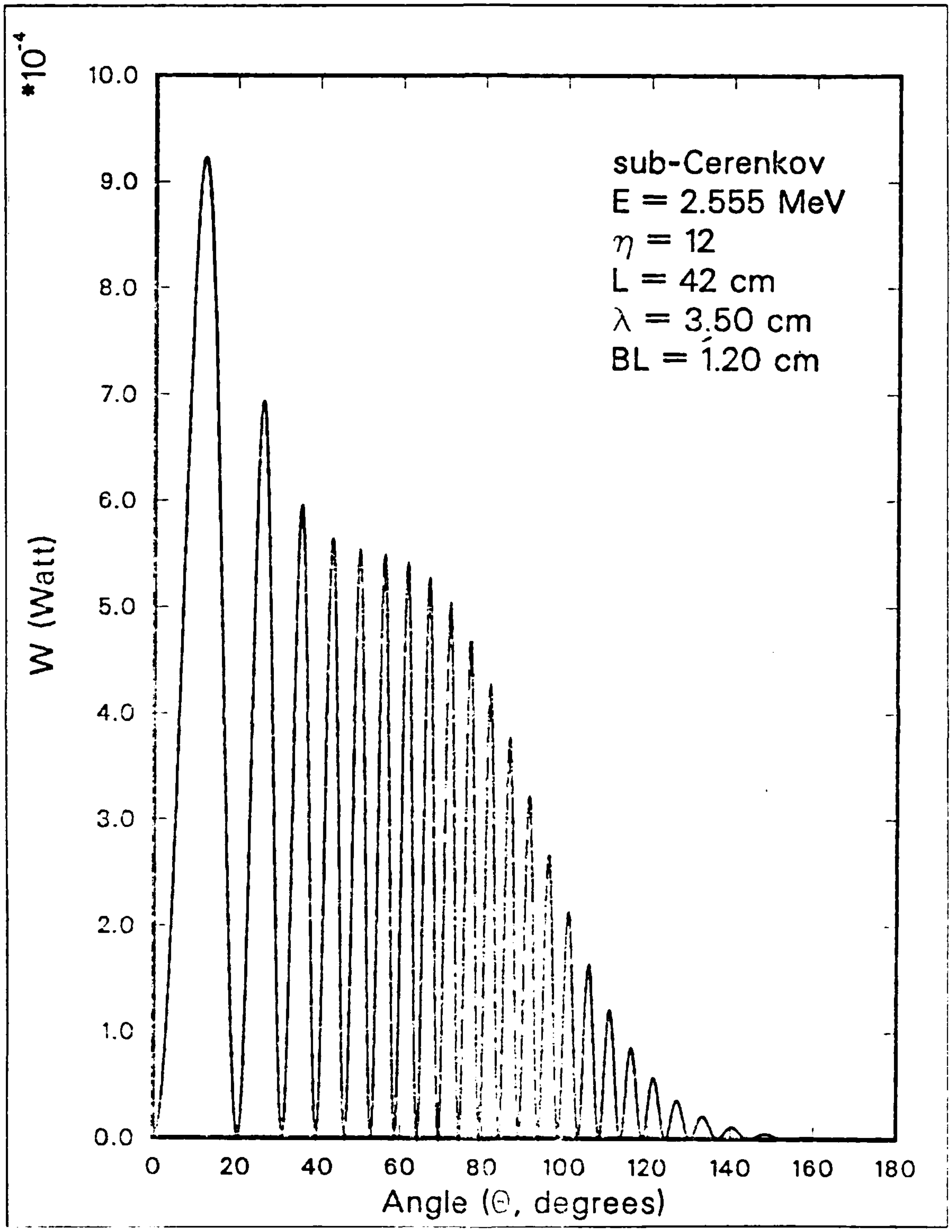


Fig. 3.2 Gaussian Function with $BL/\lambda = 0.343$, $\eta = 12$

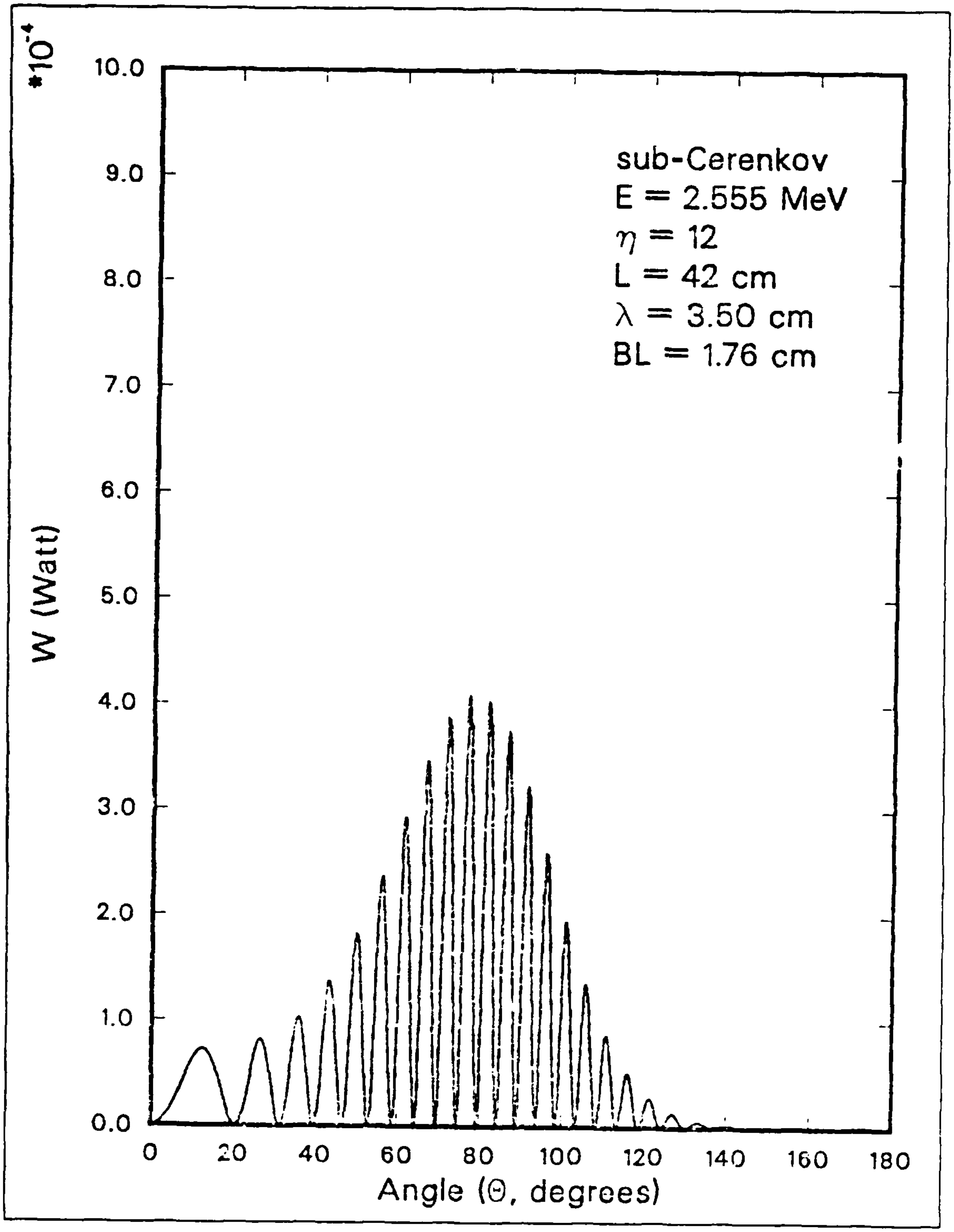


Fig. 3.3 Gaussian Function with $BL/\lambda = 0.503$, $\eta = 12$

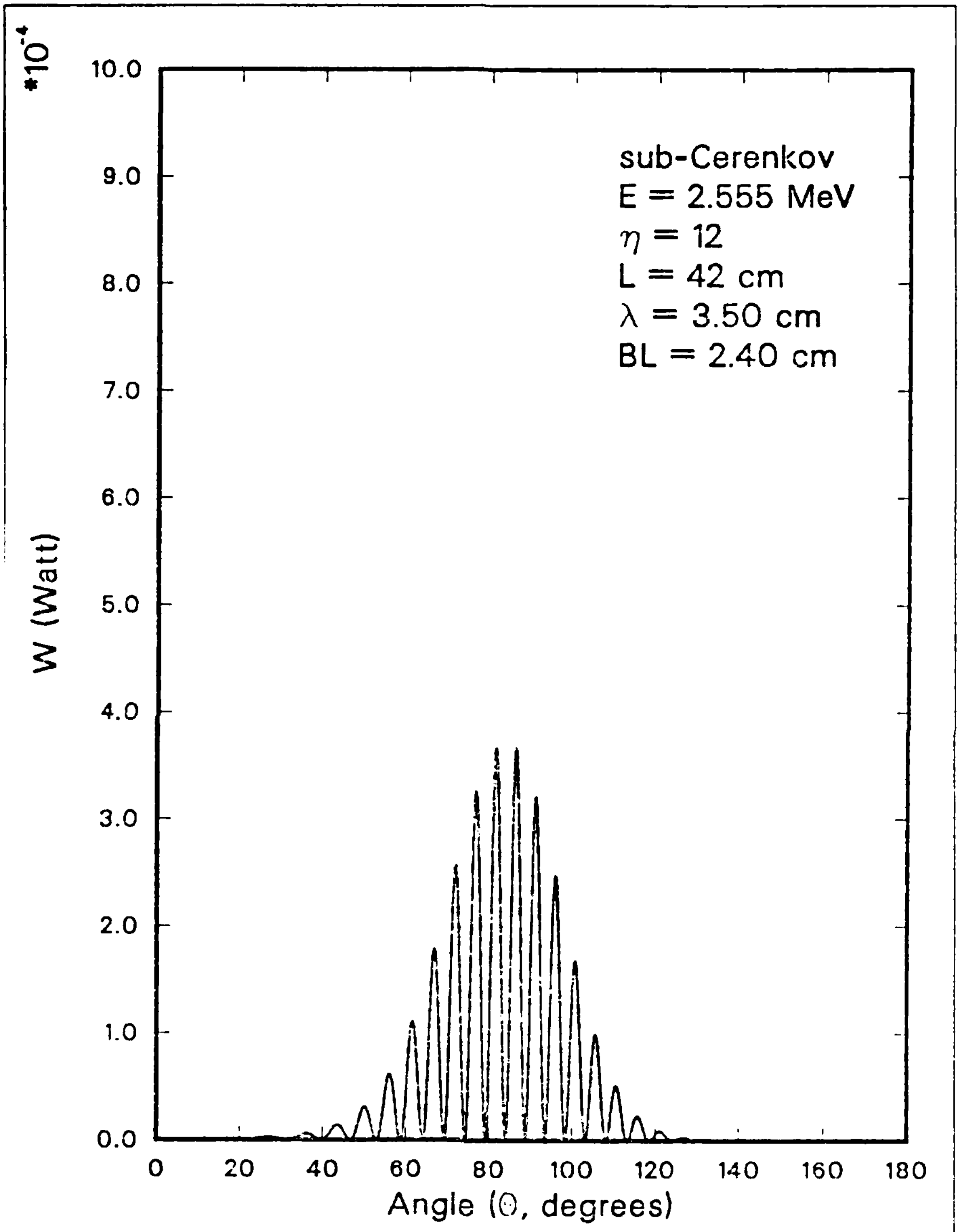


Fig. 3.4 Gaussian Function with $BL/\lambda = 0.686$, $\eta = 12$

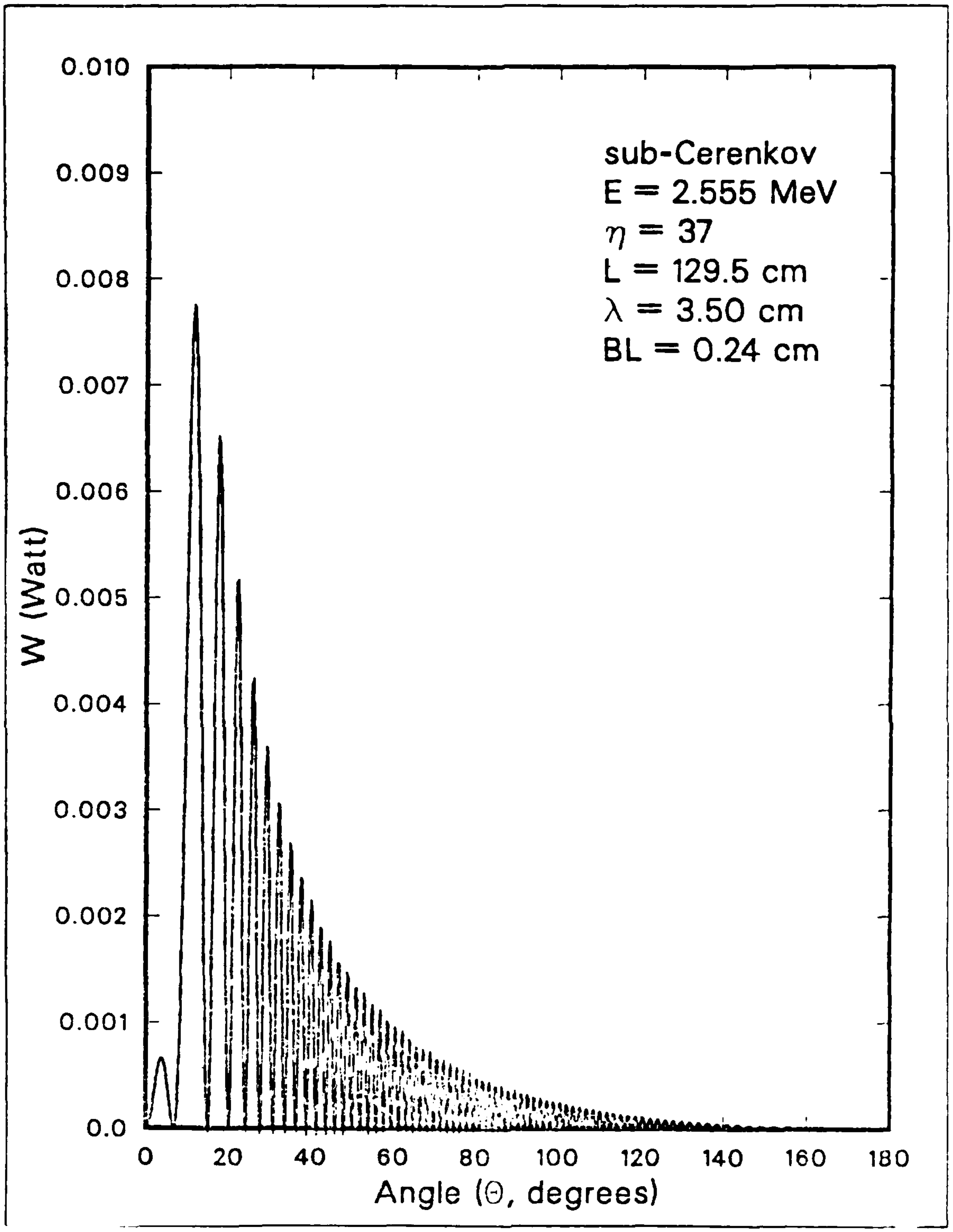


Fig. 3.5 Gaussian Function with $BL/\lambda = 0.069$, $\eta = 37$

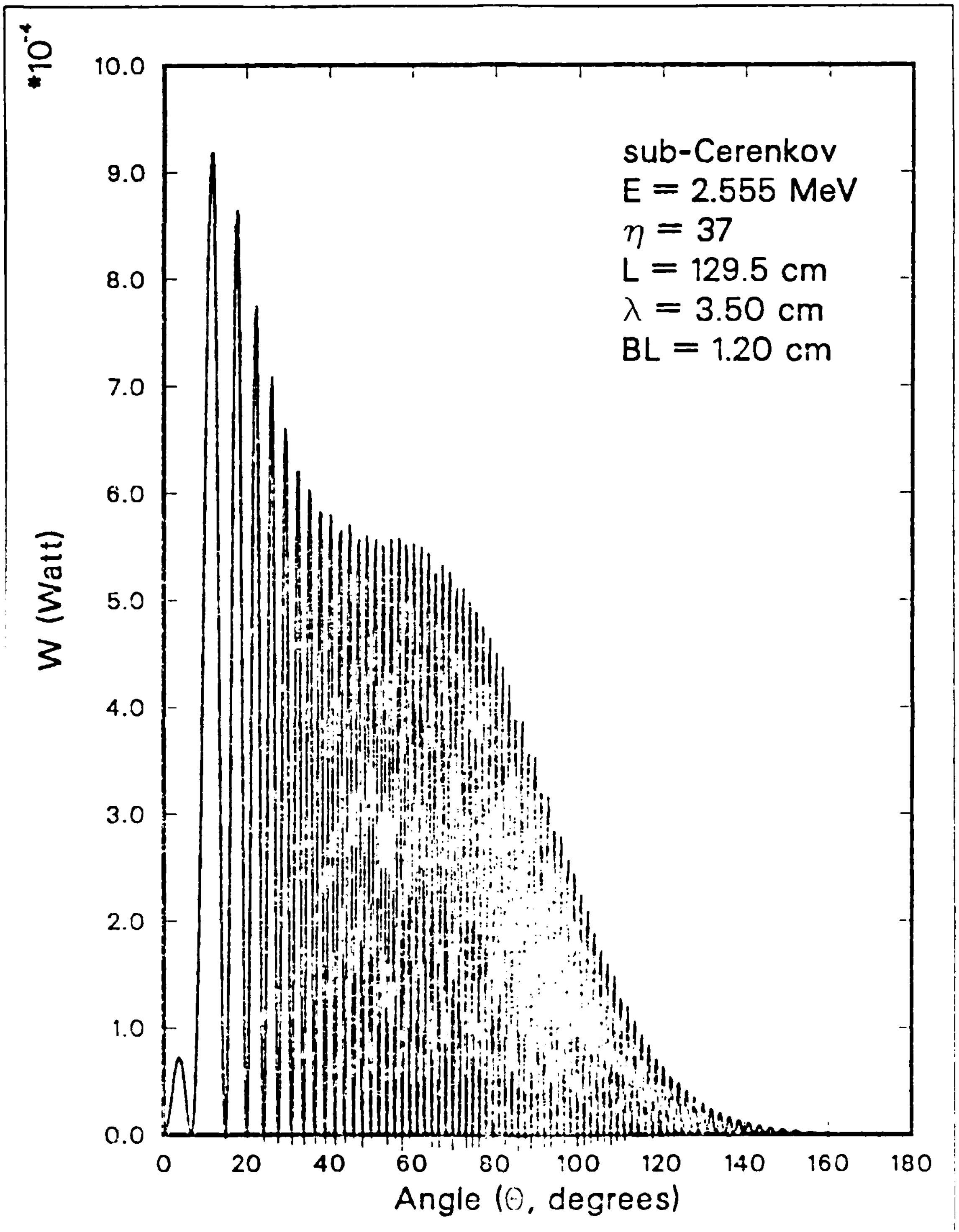


Fig. 3.6 Gaussian Function with $BL/\lambda = 0.343$, $\eta = 37$

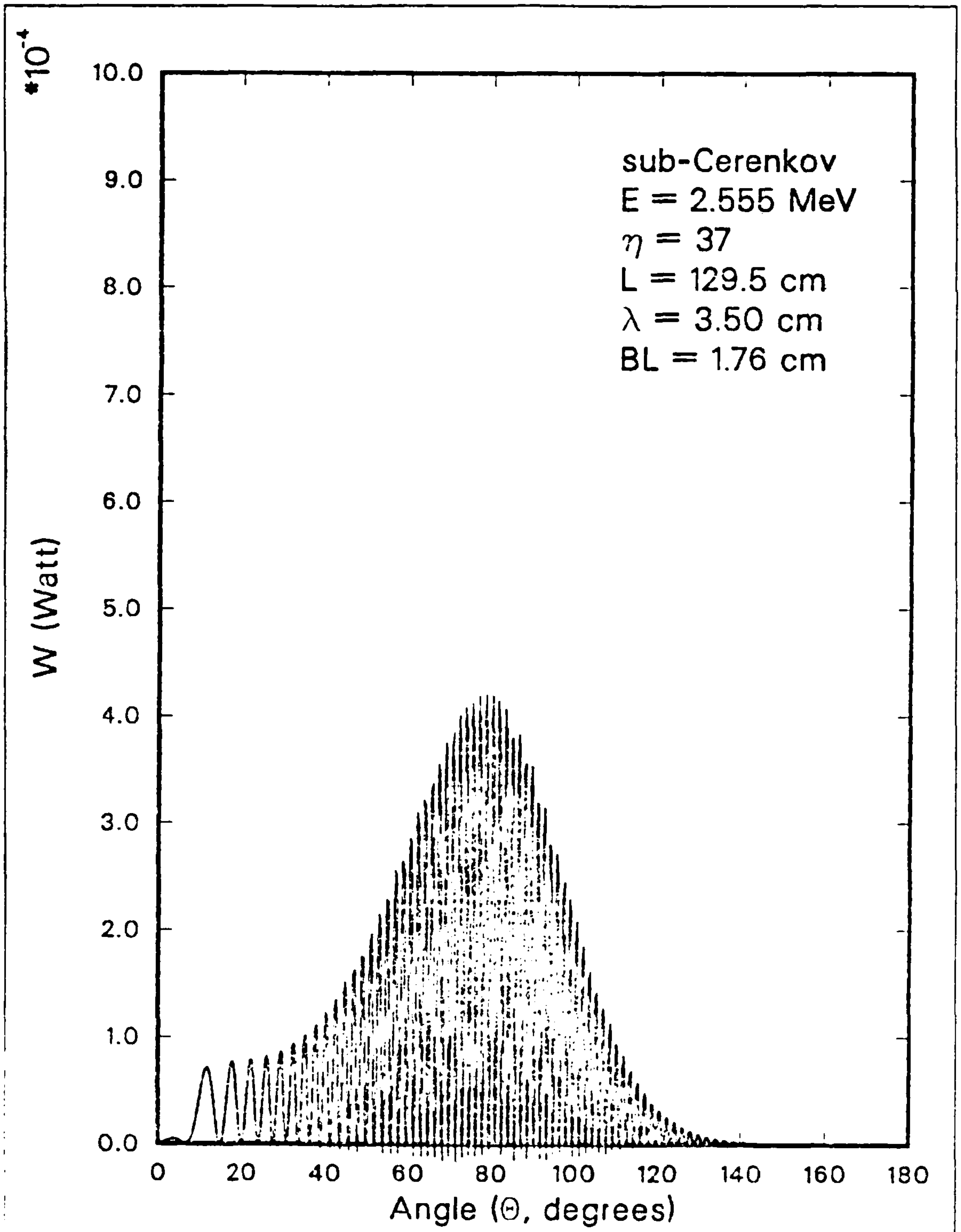


Fig. 3.7 Gaussian Function with $BL/\lambda = 0.503$, $\eta = 37$

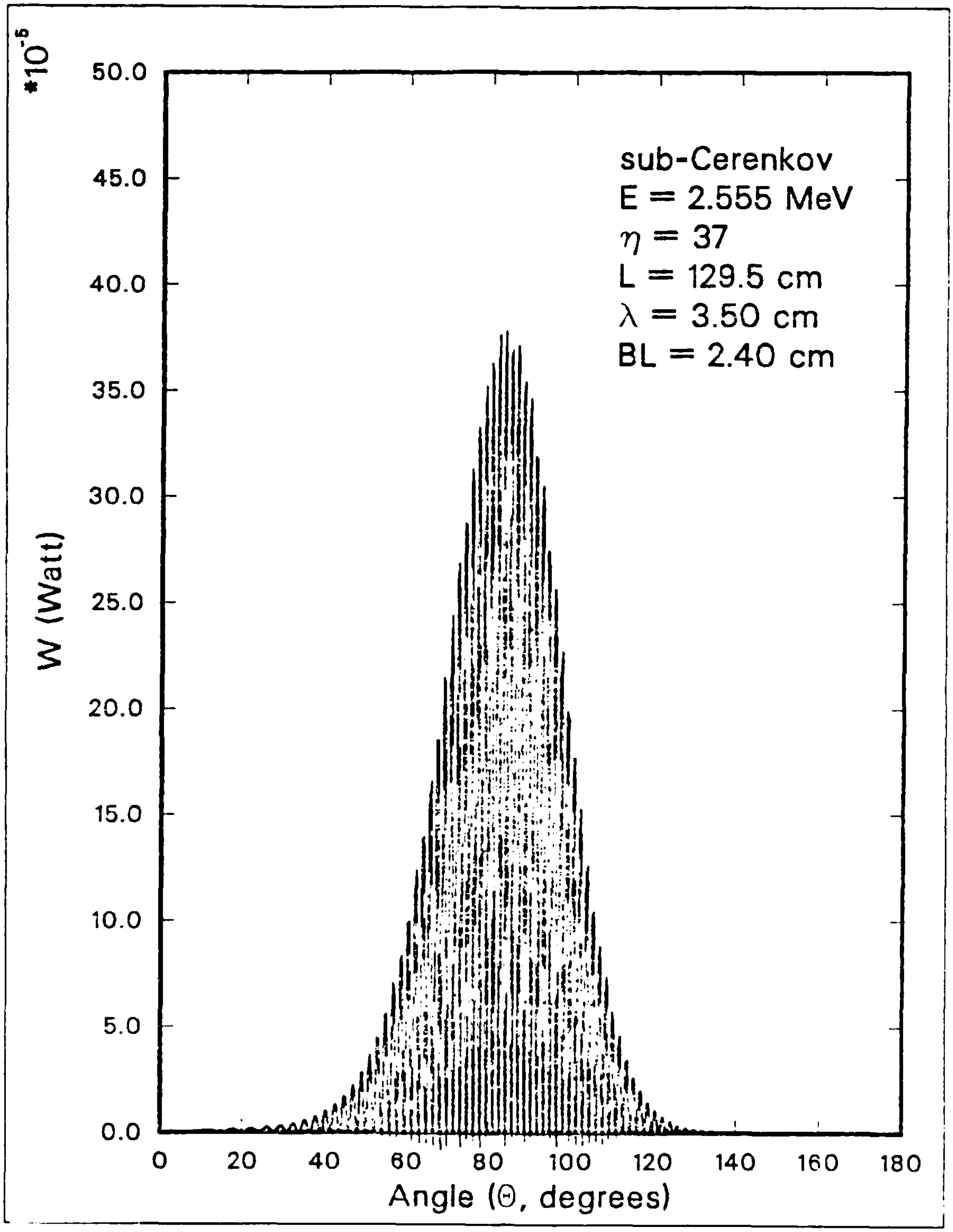


Fig. 3.8 Gaussian Function with $BL/\lambda = 0.686$, $\eta = 37$

Similar remarks can be made for the longer finite path results shown in Fig. 3.5 – 3.8 for $\eta = 37$. In this set of figures, because this value of η causes the radiation to be below threshold, the radiation patterns are wildly oscillating – almost chaotic. However exactly the same thing happens to the envelope of the radiation. Fig. 3.8, calculated for a bunch length of 2.4 cm. as is Fig. 3.4, also shows the radiation envelope to be the form factor for the Gaussian charge distribution.

C. LEVEL FUNCTION

Fig. 3.9 through Fig. 3.22 show the radiation intensity lobe development as the level function charge distribution length varies for the same two values of η. Fig. 3.9 through Fig. 3.15 are calculated for $\eta = 12$, the remainder through Fig. 3.22 for $\eta = 37$. LFL is the symbol for the level function length.

In Fig. 3.9, where the level function length is much smaller than the radiation length, the radiation pattern is almost the same shape as Fig. 3.1 which is for the Gaussian charge distribution. Proceeding through to Fig. 3.13, as the length of the charge distribution is increased the form factor becomes prominent. Fig. 3.13 is of interest in that it also shows considerable radiation at small angles. This result occurs because the form factor for the level function has secondary maximum which at low angles combine with the relatively large value of the diffraction function to give substantial radiation.

Further increases in level function length give an increased role to the form factor until finally in Fig. 3.15, it has become dominant. Here the envelope of the radiation is seen to be the (skewed) form factor of the level function. The small lone peak at approximately ten degrees occurs at the maximum of the geometrical envelope function.

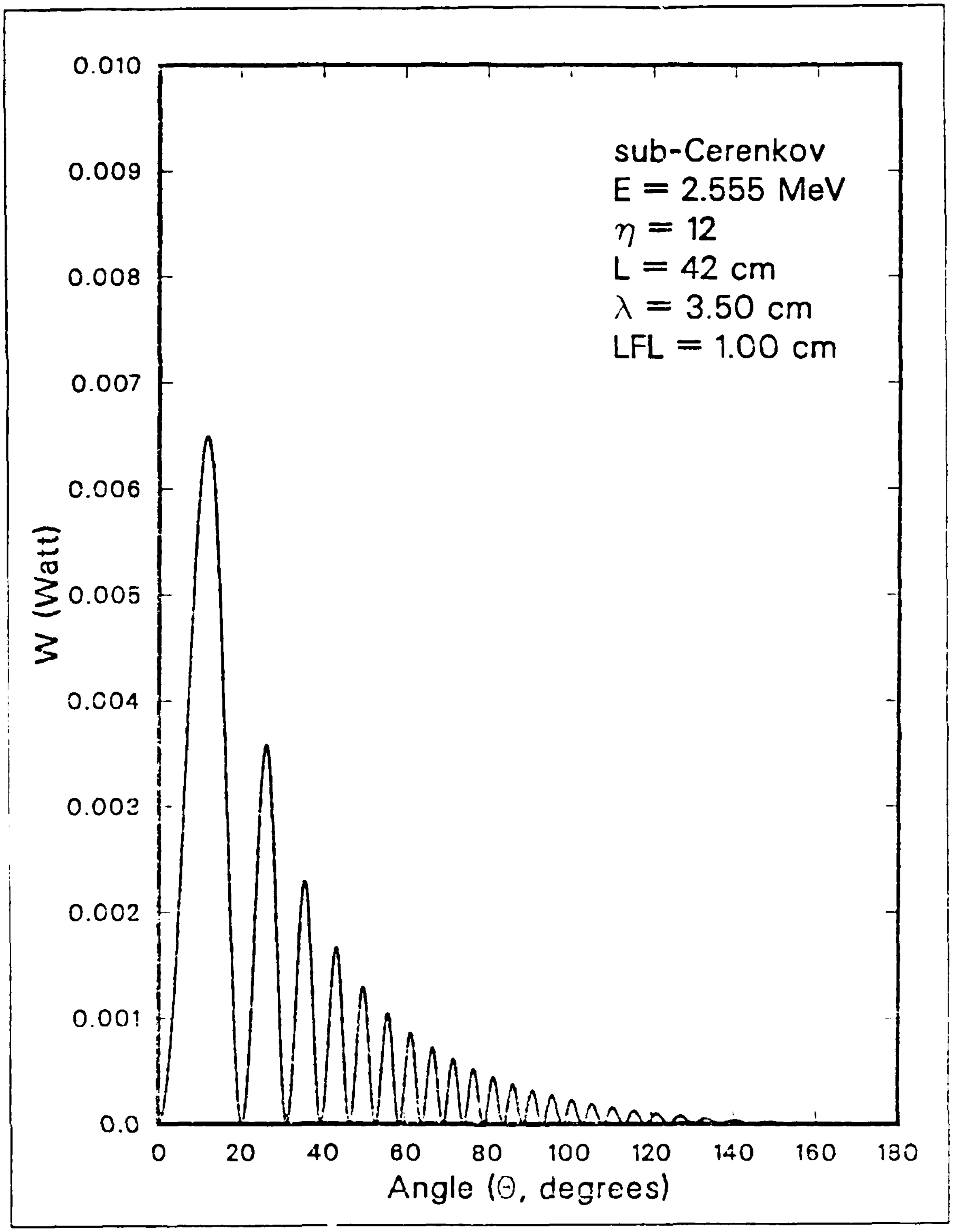


Fig. 3.9 Level Function with $LFL/\lambda = 0.285$, $\eta = 12$

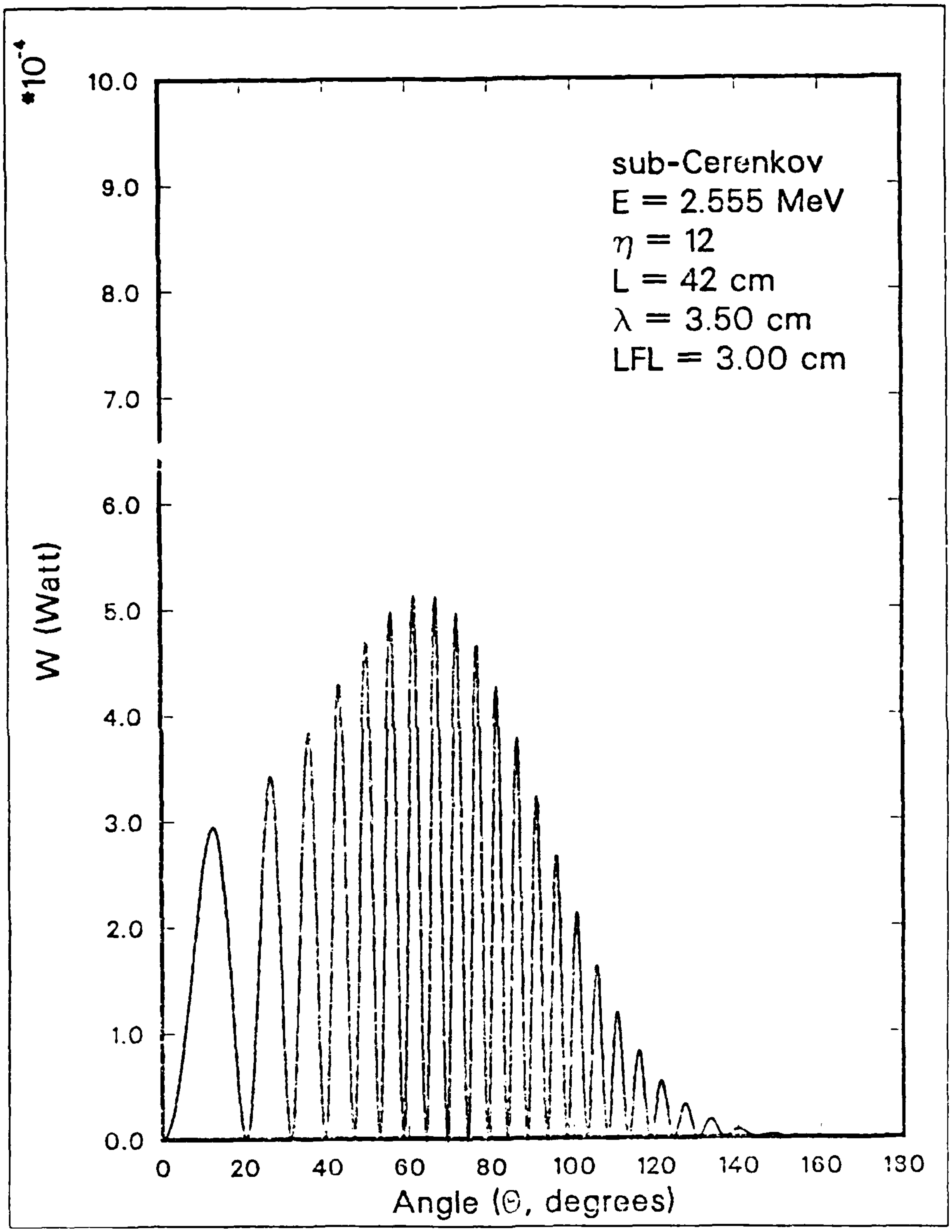


Fig. 3.10 Level Function with $LFL/\lambda = 0.855$, $\eta = 12$

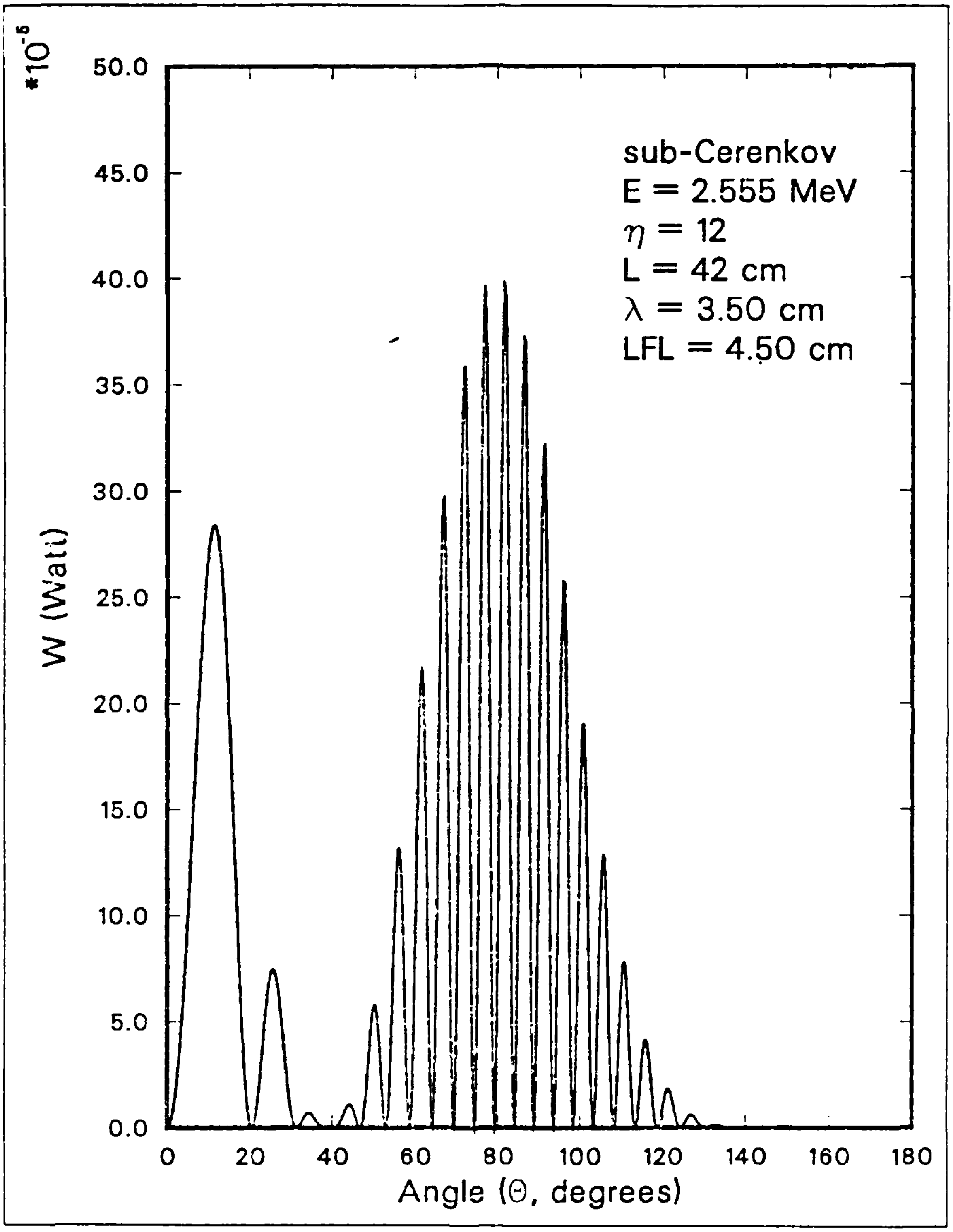


Fig. 3.11 Level Function with $LFL/\lambda = 1.28$, $\eta = 12$

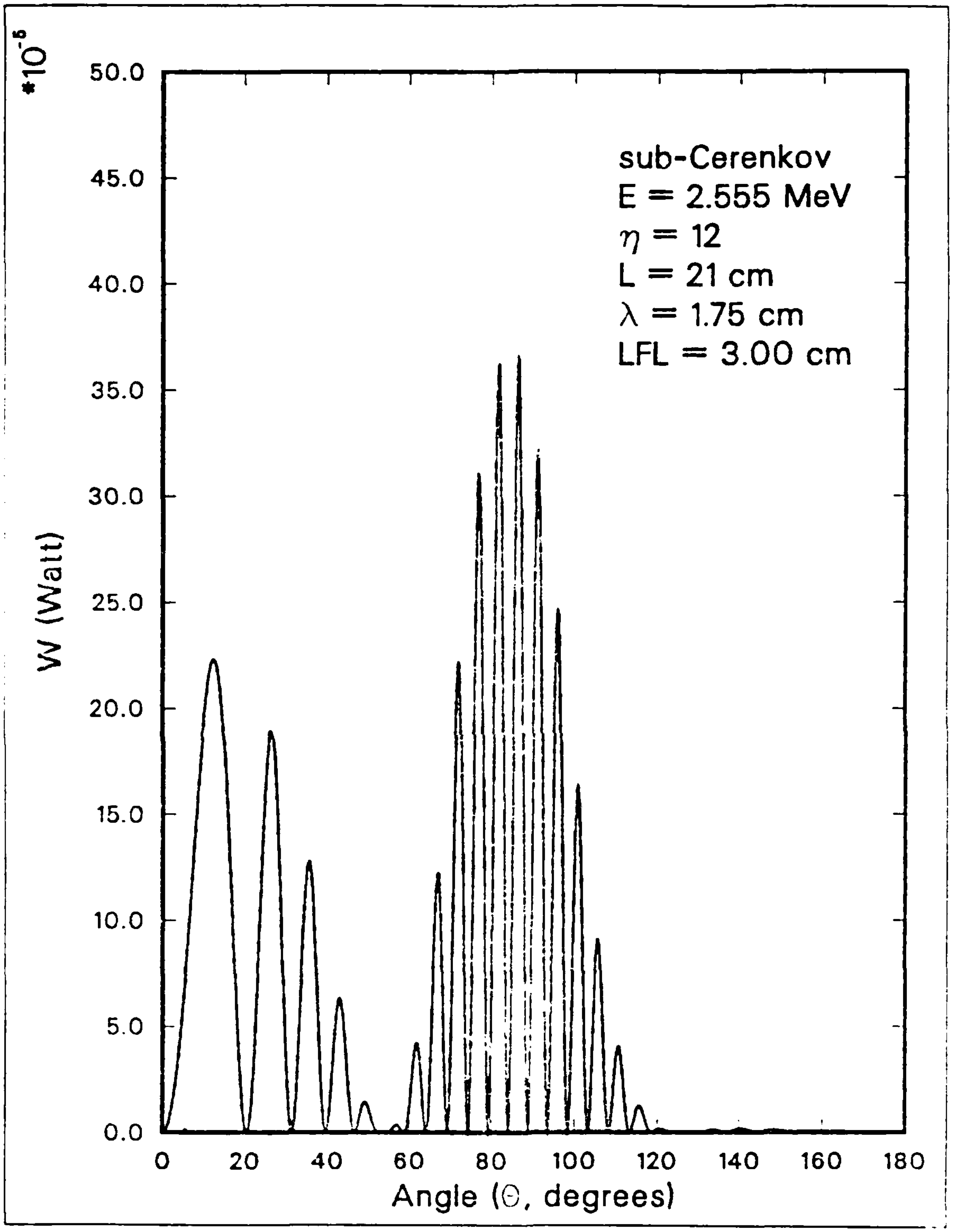


Fig. 3.12 Level Function with $LFL/\lambda = 1.71$, $\eta = 12$

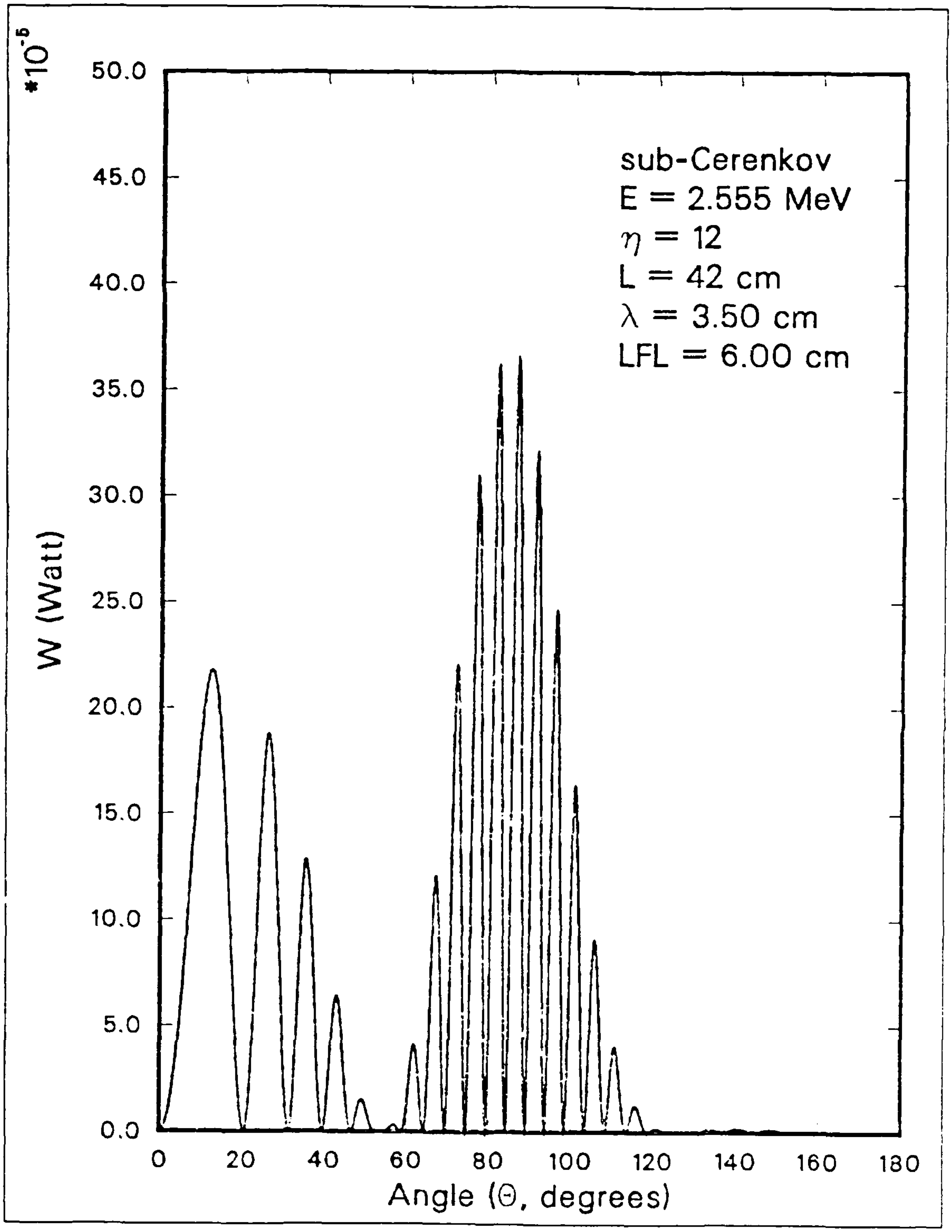


Fig. 3.13 Level Function with LFL/λ = 1.71, η = 12

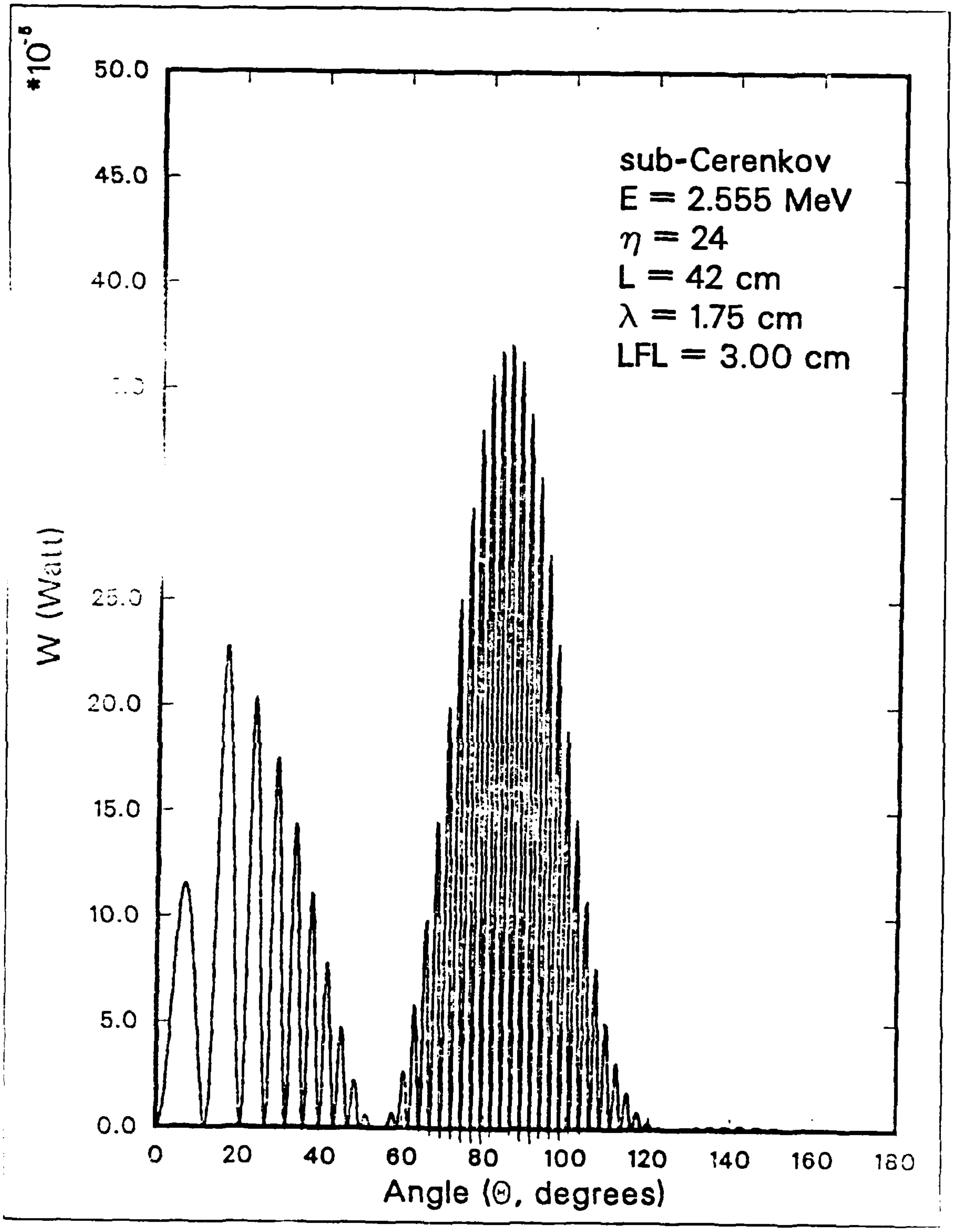


Fig. 3.14 Level Function with LFl/λ = 1.71, η = 24

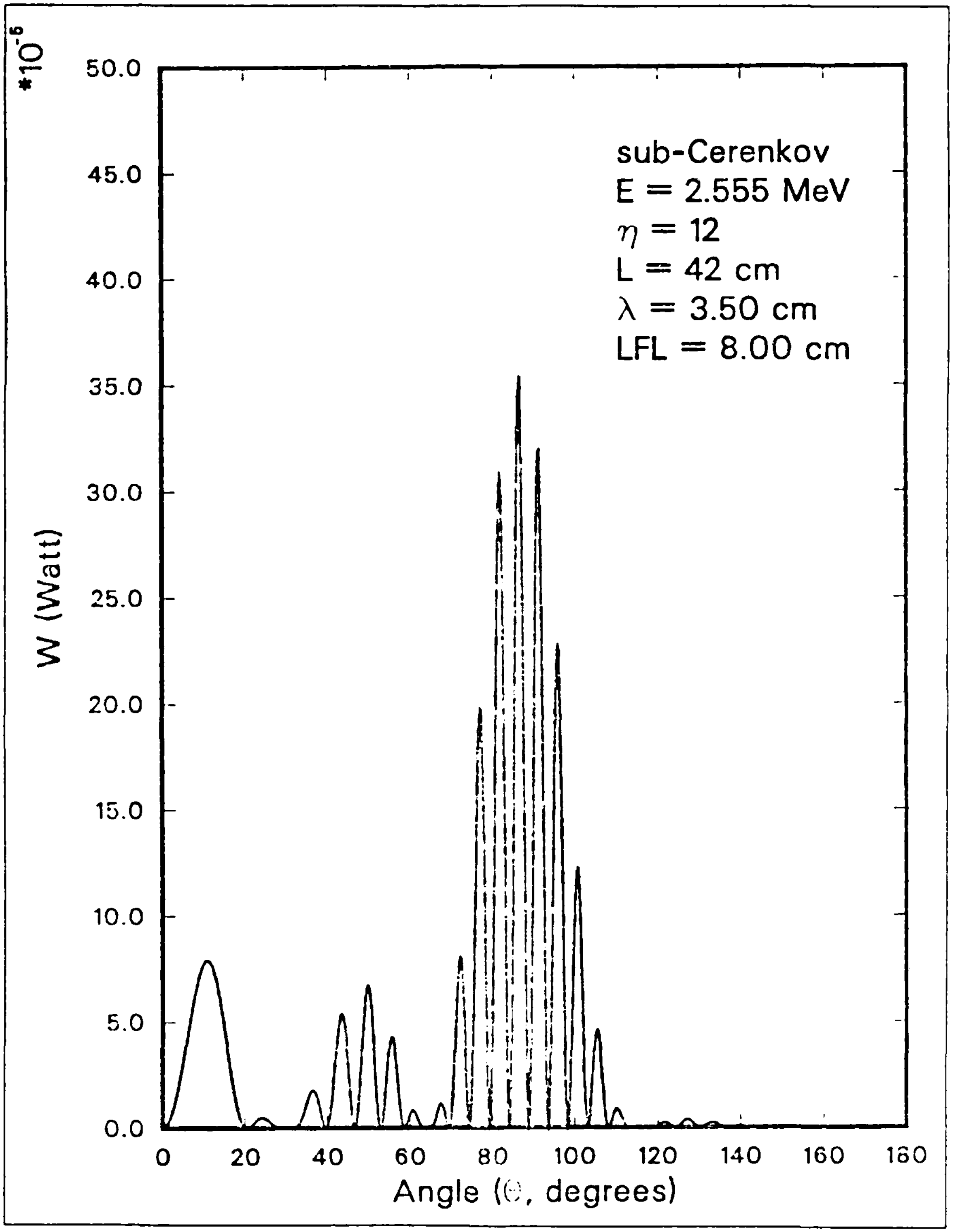


Fig. 3.15 Level Function with $LFL/\lambda = 2.28$, $\eta = 12$

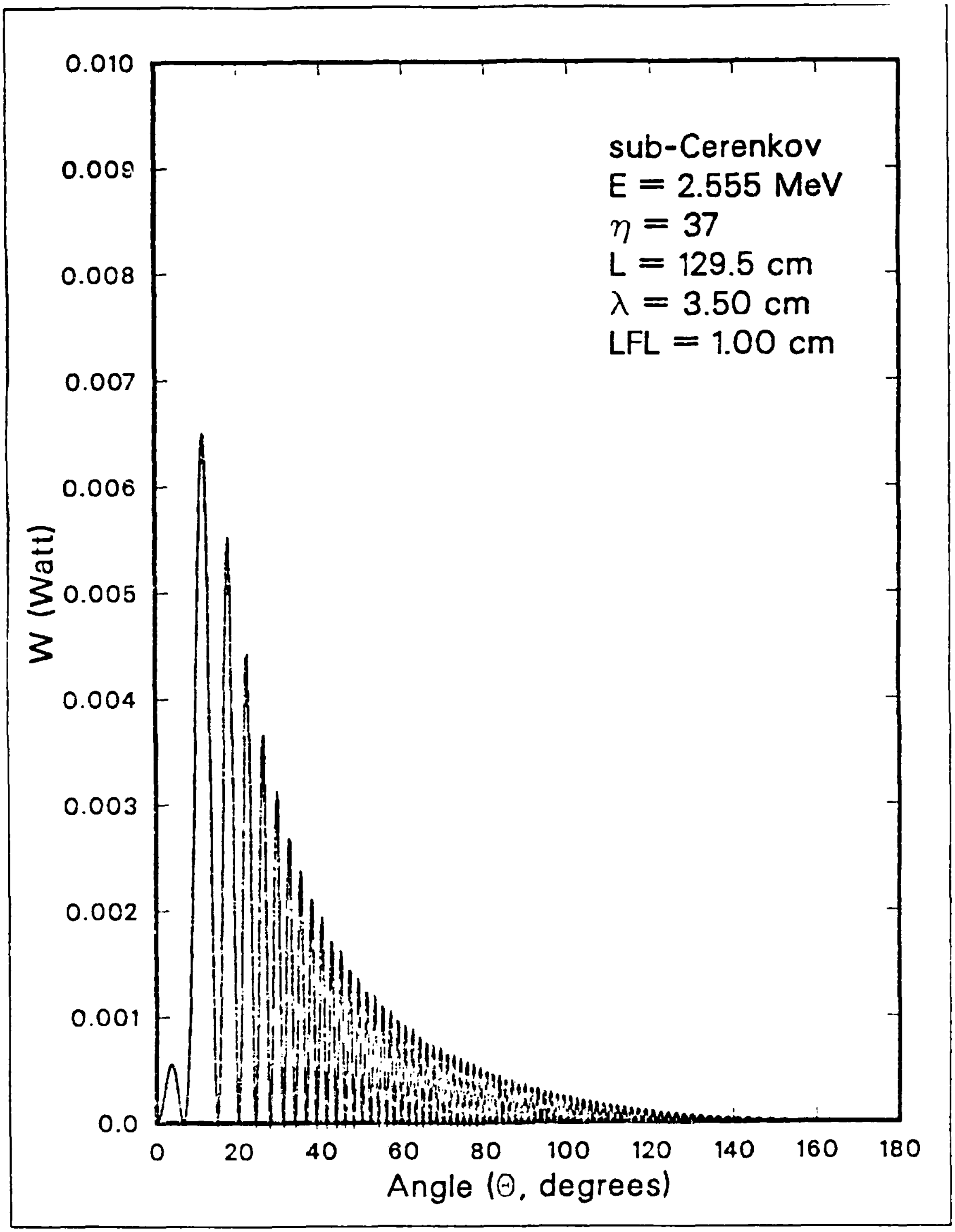


Fig. 3.16 Level Function with LFL/λ = 0.29, η = 37

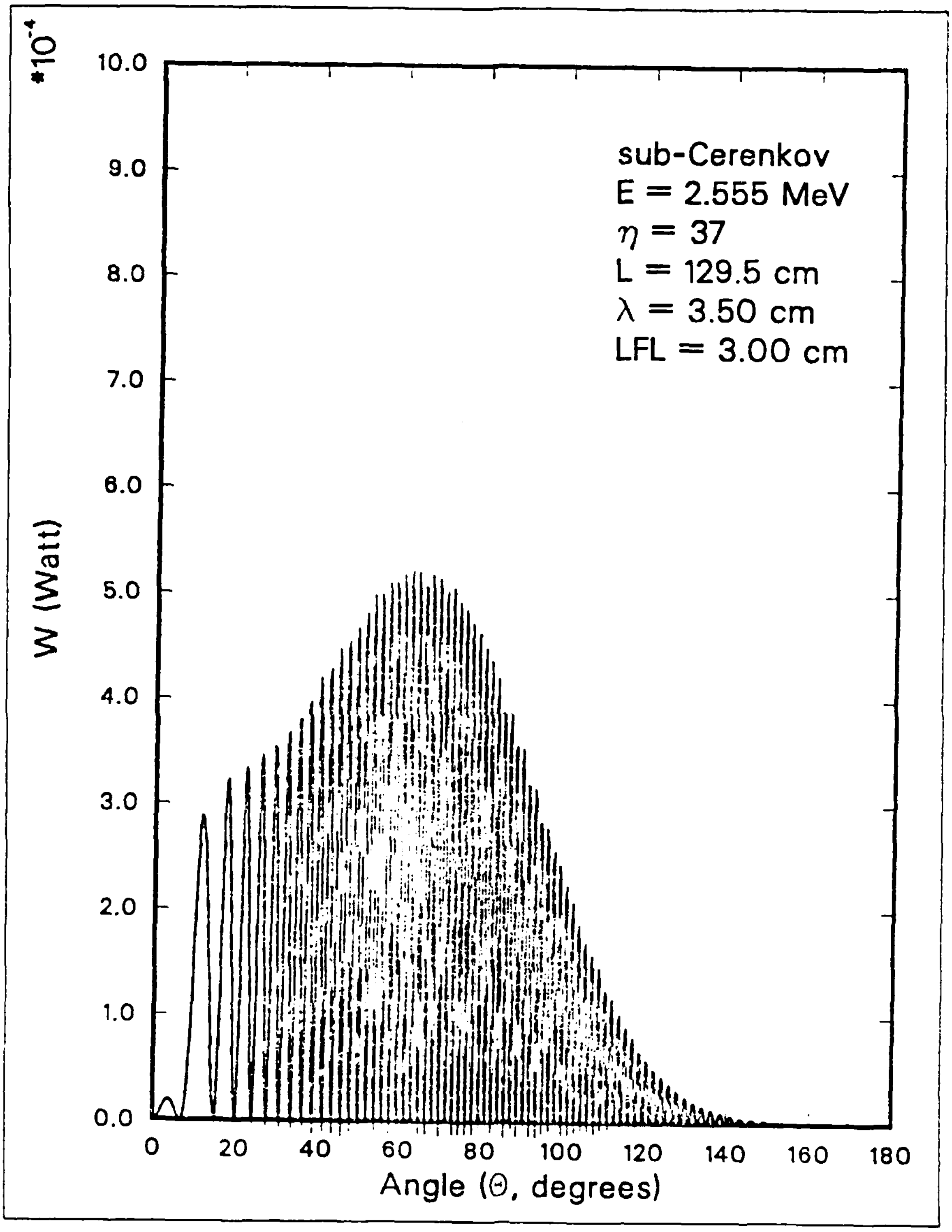


Fig. 3.17 Level Function with LFL/λ = 0.85, η = 37

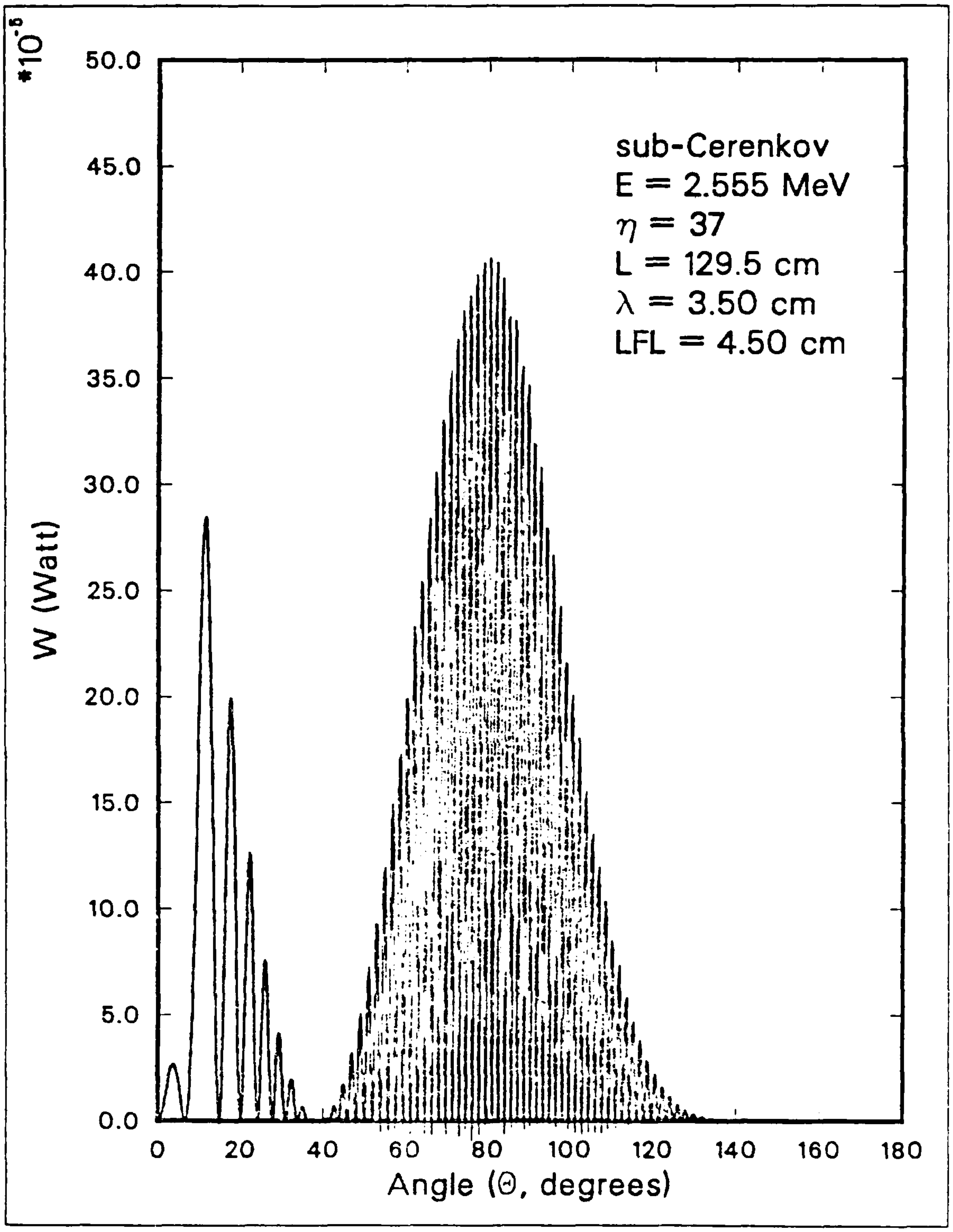


Fig. 3.18 Level Function with LFL/λ = 1.28, η = 37

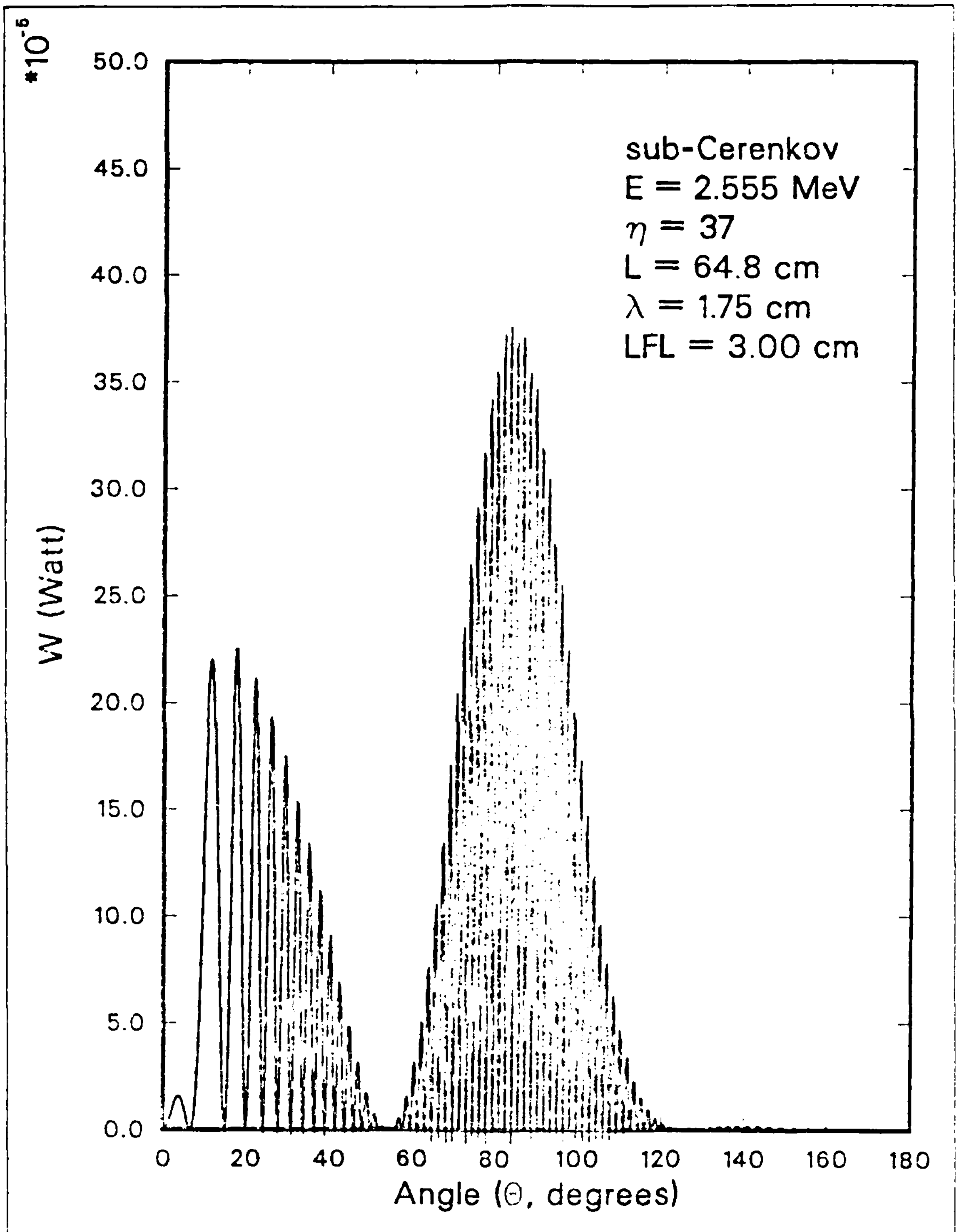


Fig. 3.19 Level Function with $LFL/\lambda = 1.71$, $\eta = 37$

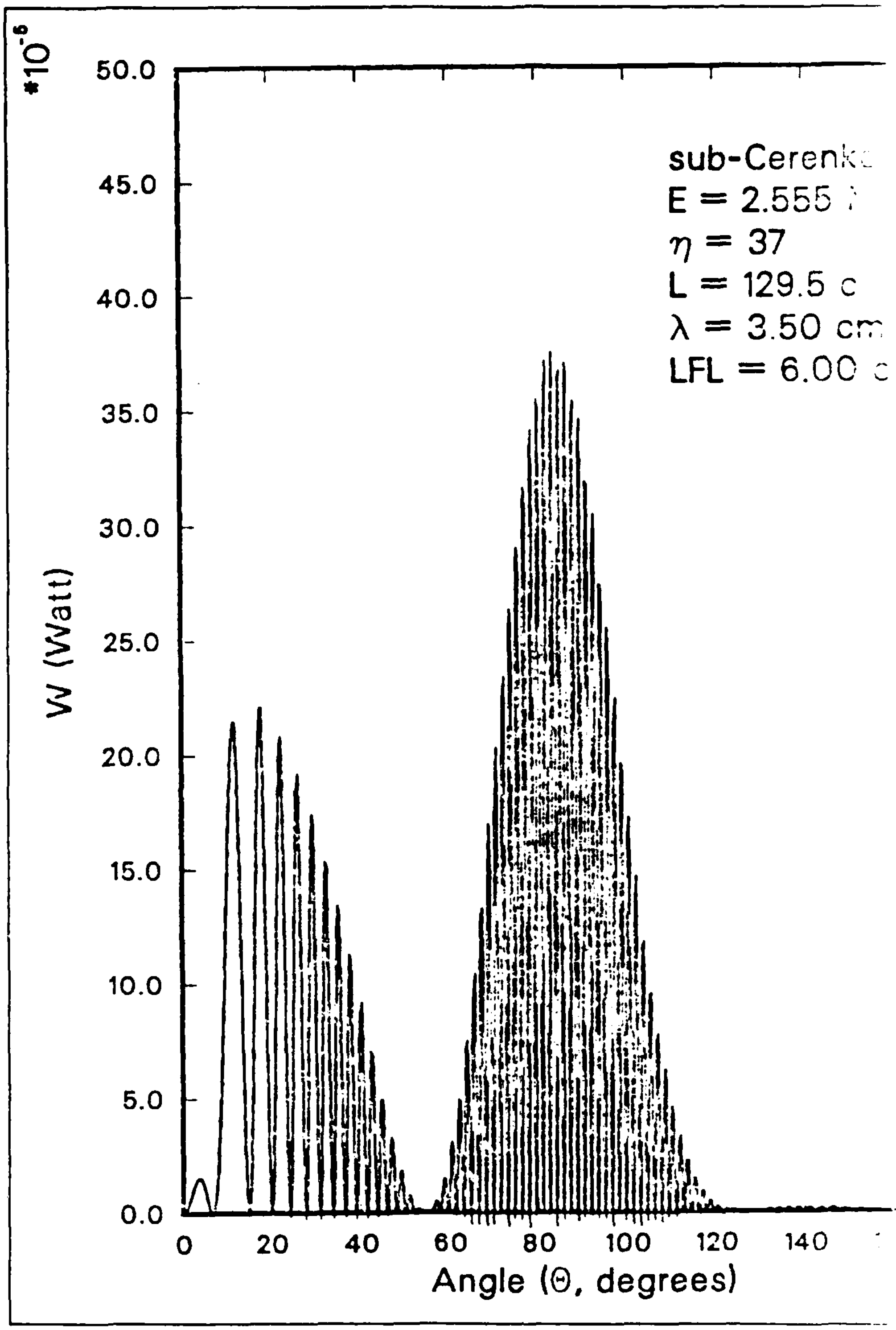


Fig. 3.20 Level Function with LFL/λ = 1.71, η = 37

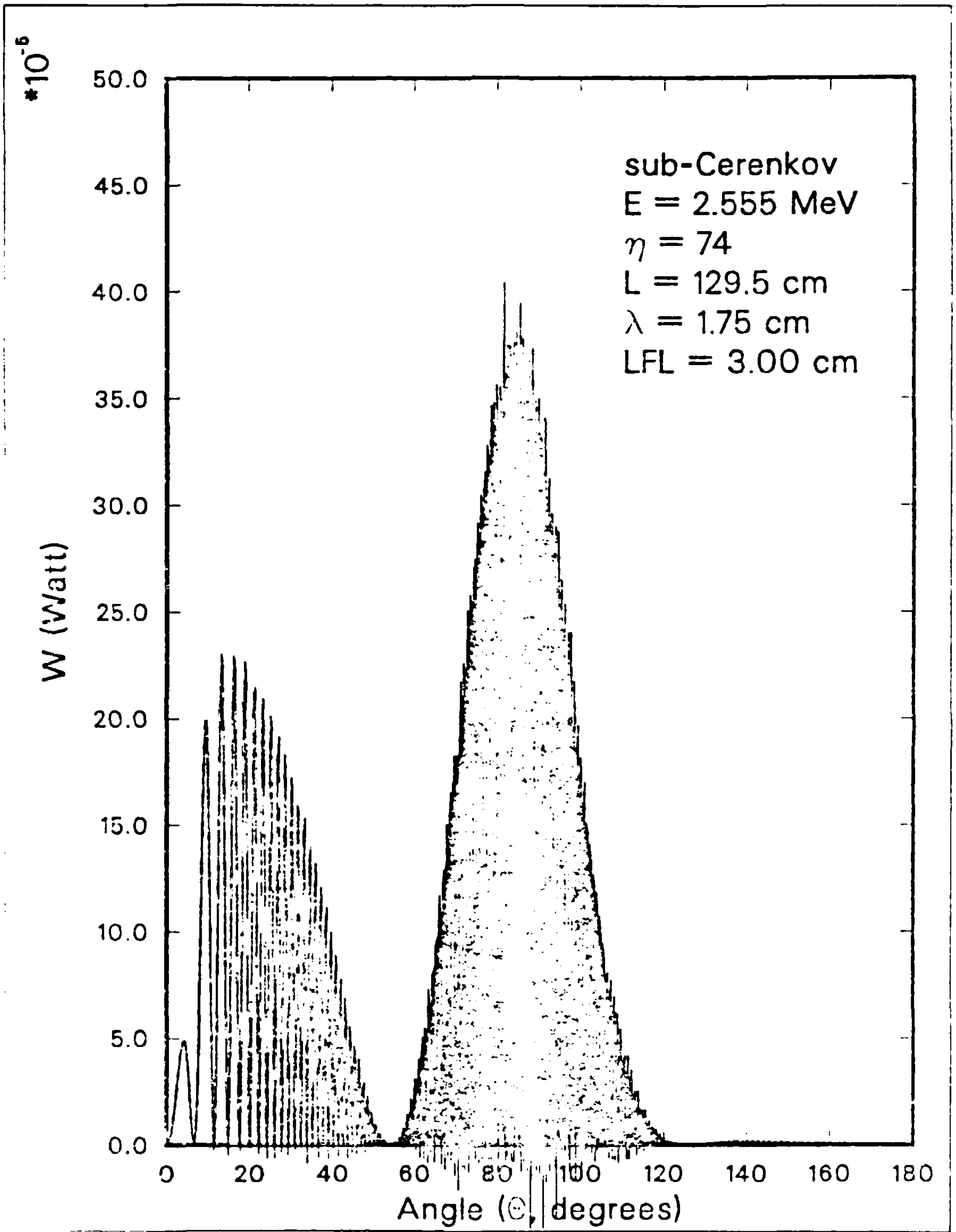


Fig. 3.21 Level Function with $LFL/\lambda = 1.71$, $\eta = 74$

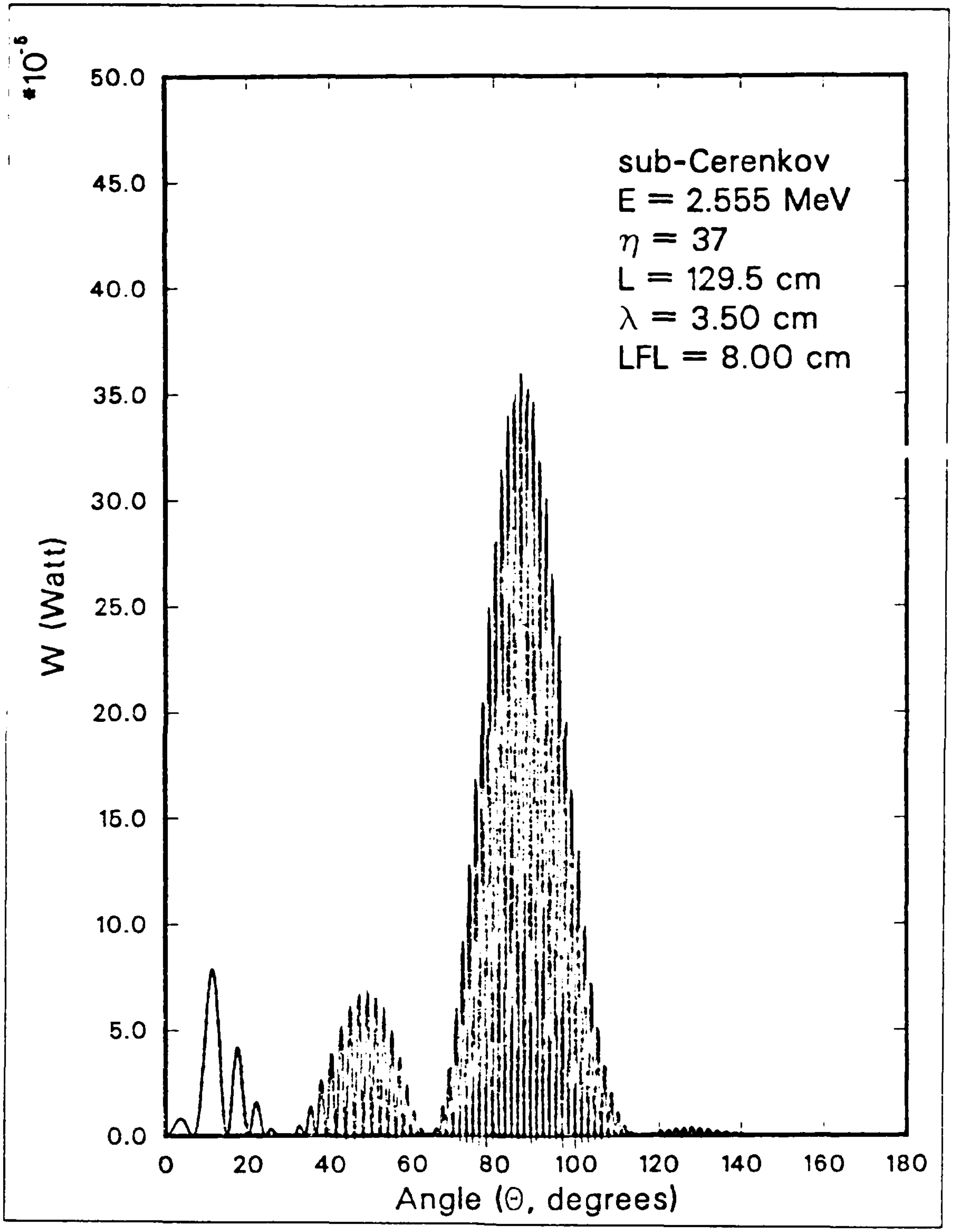


Fig. 3.22 Level Function with $LFL/\lambda = 2.28$, $\eta = 37$

Fig. 3.16 to Fig. 3.22 drawn for $\eta = 37$ show the increasing dominance of the form factor below threshold. The pattern oscillates very rapidly, but otherwise the results are as above. In fact the rapid oscillations make the form factor more evident in this series of figures.

D. TRAPEZOIDAL FUNCTION

Both the Gaussian and level function distributions have a single characteristic length; the trapezoid is more complicated in having two, the length of the base, l_b, and the length of the top, l_t. In the fourier transform these appear as $\ell = (l_b + l_t)/2$ and $l = (l_b - l_t)/2$.

Fig. 3.23 through 3.32 show radiation patterns for a trapezoidal charge distribution for different values of top and base lengths. All except the last three, Fig. 3.30 through Fig. 3.32 are for $\eta = 12$. TFTL is the symbol for the top level length of the trapezoidal function and TFBL, for the base level length of trapezoidal function.

As mentioned earlier, the form factor is sensitive to the ratios of the characteristic lengths to the wavelength of the emitted radiation. Here the appropriate ratios are ℓ/η and l/λ. In Fig. 3.23 both these ratios are less than one so that the radiation pattern is characteristic of a point charge distribution. Fig. 3.24 drawn for ℓ/λ 1.2 and $l/\lambda = 0.29$ shows a different pattern with the form factor already becoming quite evident.

Fig. 3.25 through Fig. 3.27, calculated for a constant slightly larger ratio of $\ell/\lambda = 1.71$, and increasing values of l/λ are all similar since the radiation wavelength is too large to be sensitive to the smaller details of the charge distribution. The same comment applies also to Fig. 3.28 for which ℓ/λ is still larger but l/λ is less than one.

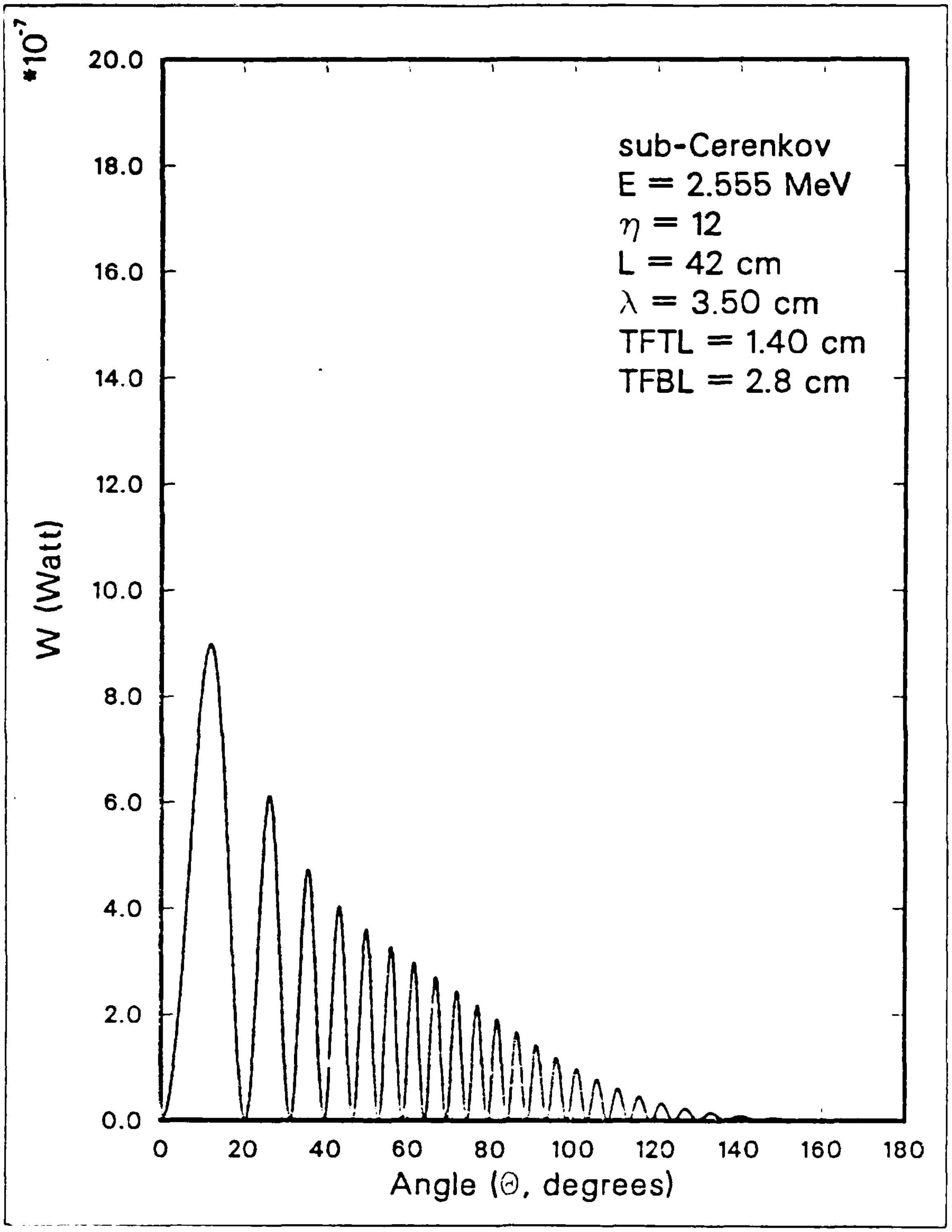


Fig. 3.23 Trapezoidal Function with $\ell/\lambda = 0.60$, $1/\lambda = 0.20$

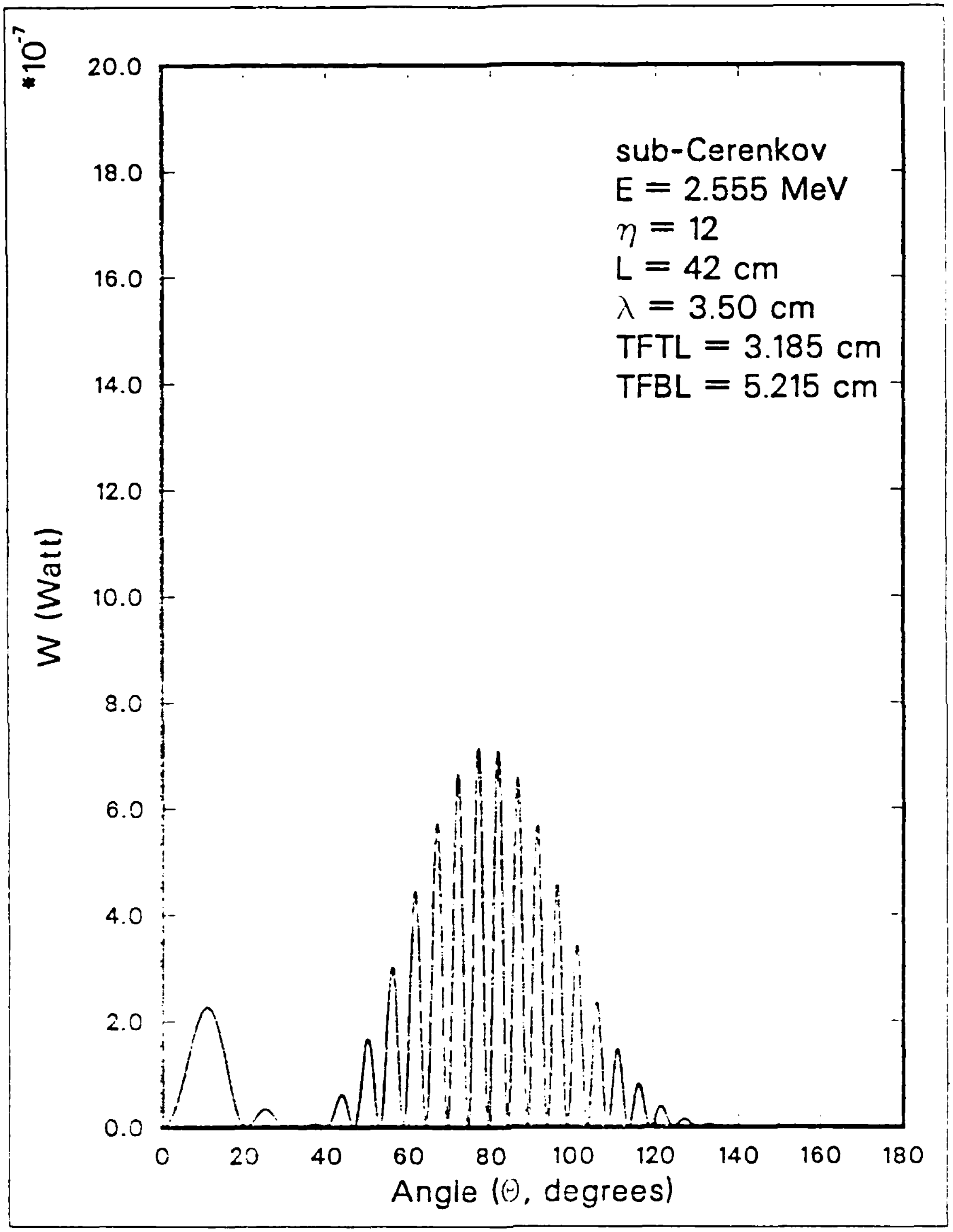


Fig. 3.24 Trapezoidal Function with ℓ/λ = 1.20, $1/\lambda$ = 0.29

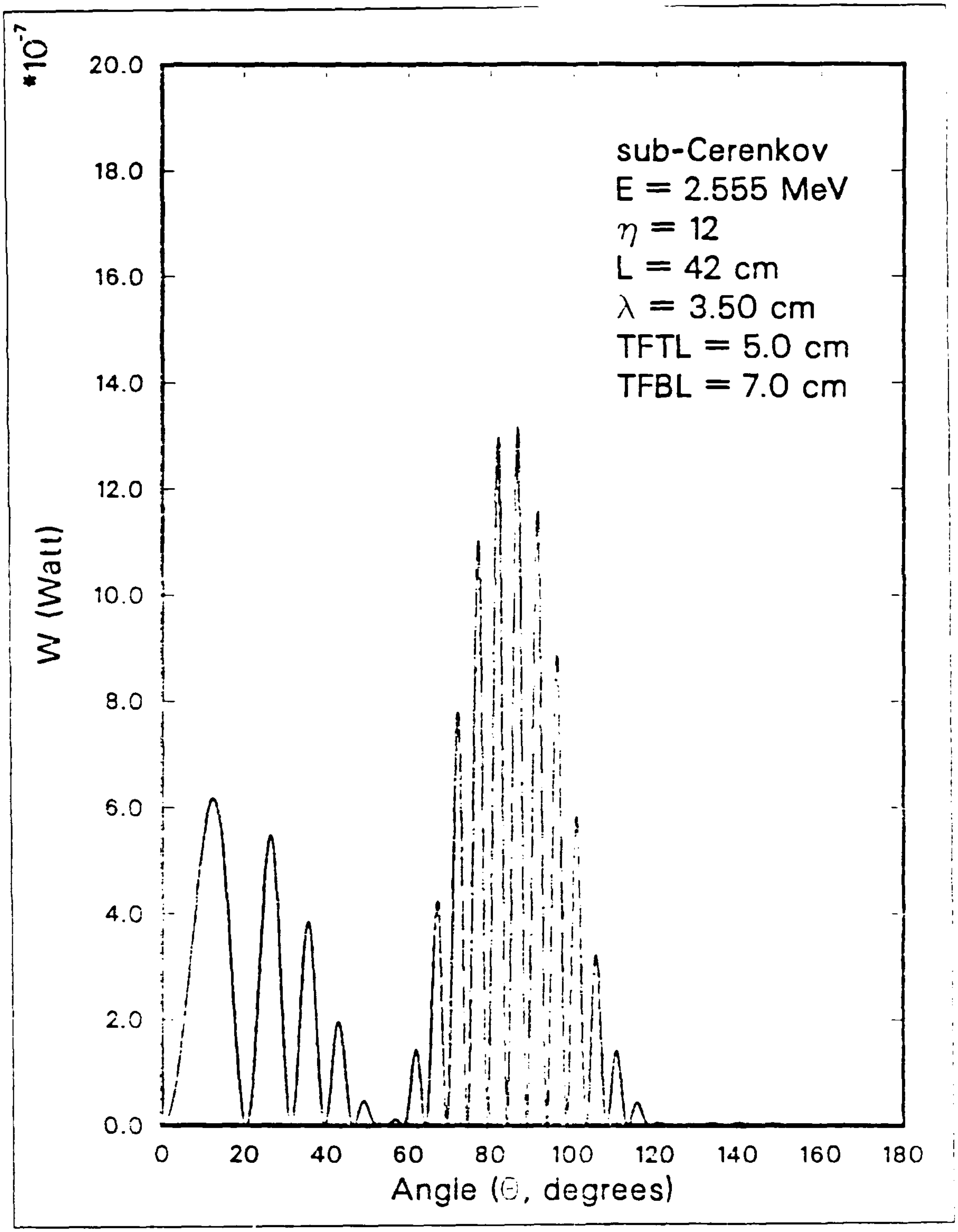


Fig. 3.25 Trapezoidal Function with $\ell/\lambda = 1.71$, $1/\lambda = 0.29$

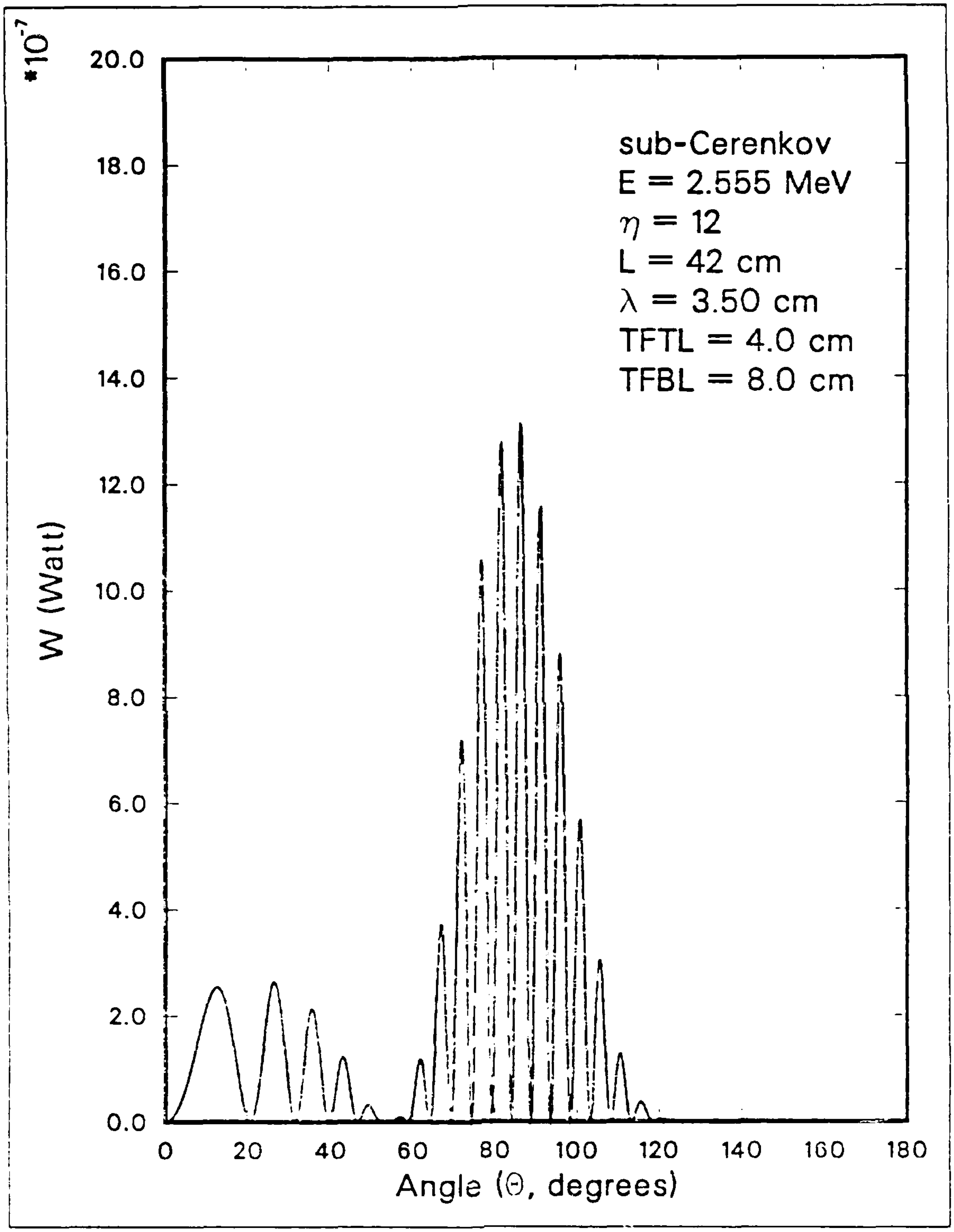


Fig. 3.26 Trapezoidal Function with ℓ/λ = 1.71, l/λ = 0.57

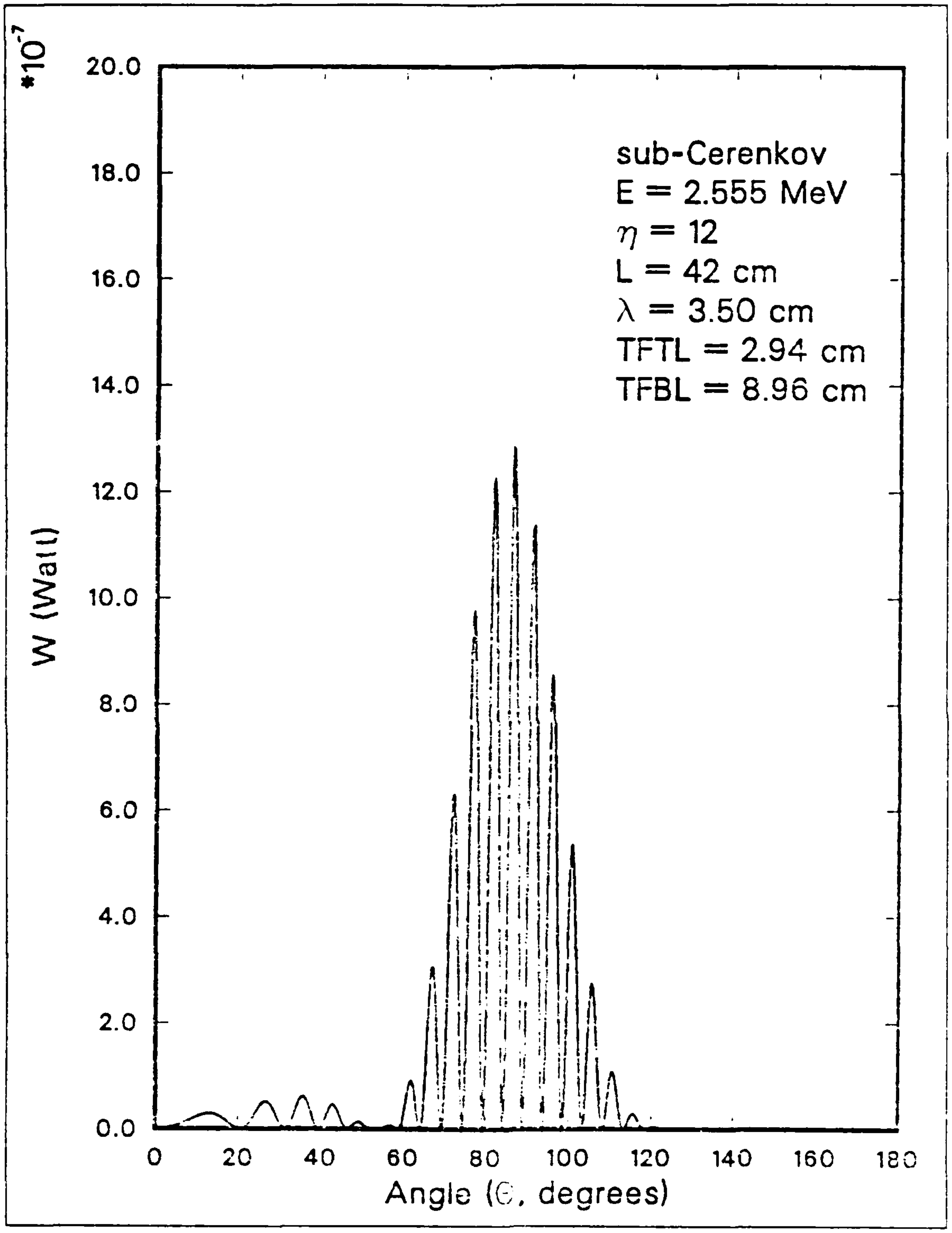


Fig. 3.27 Trapezoidal Function with ℓ/λ = 1.71, $1/\lambda$ = 0.86

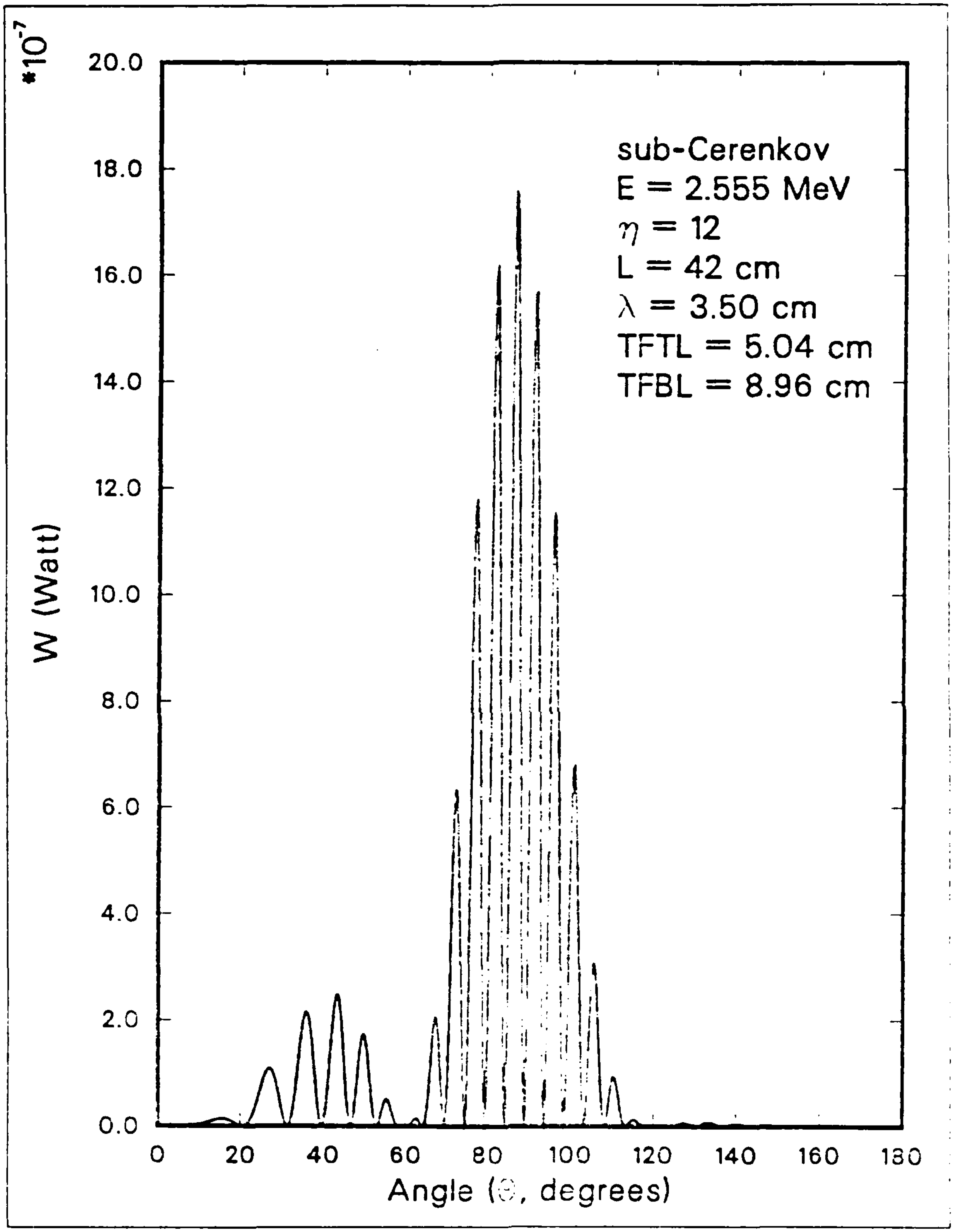


Fig. 3.28 Trapezoidal Function with ℓ/λ = 2.00, l/λ = 0.56

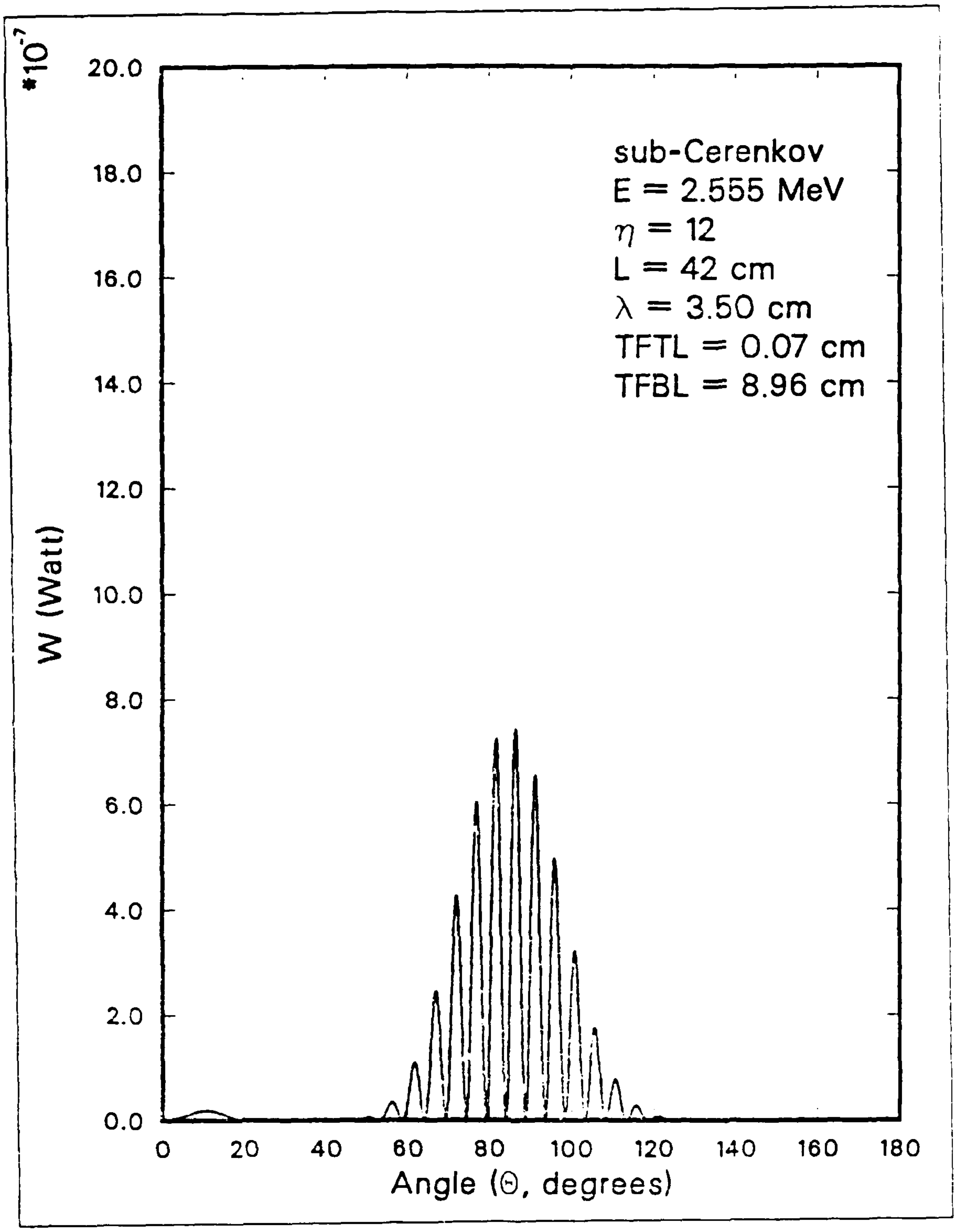


Fig. 3.29 Trapezoidal Function with ℓ/λ = 1.29, l/λ = 1.27

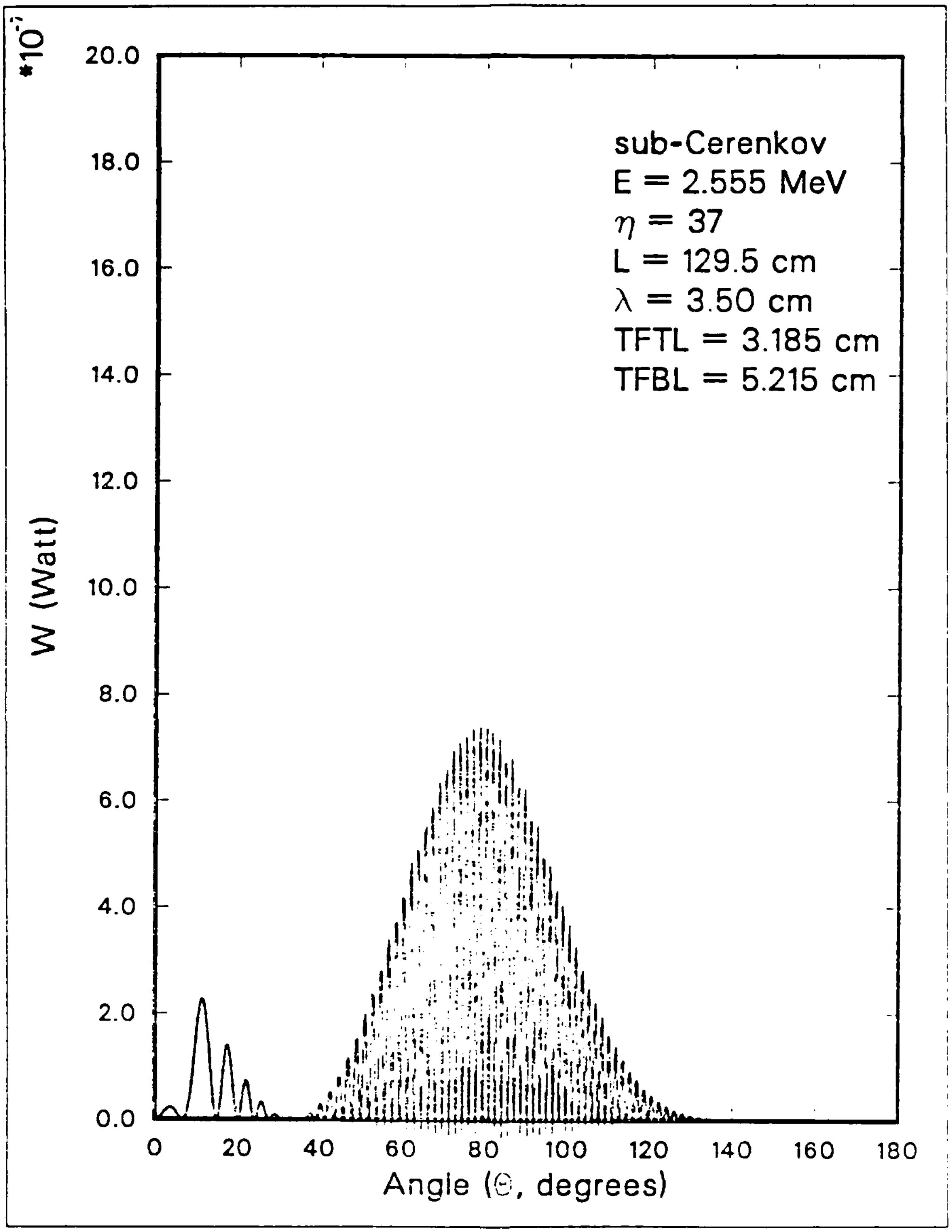


Fig. 3.30 Trapezoidal Function with $\ell/\lambda = 1.20$, $1/\lambda = 0.29$

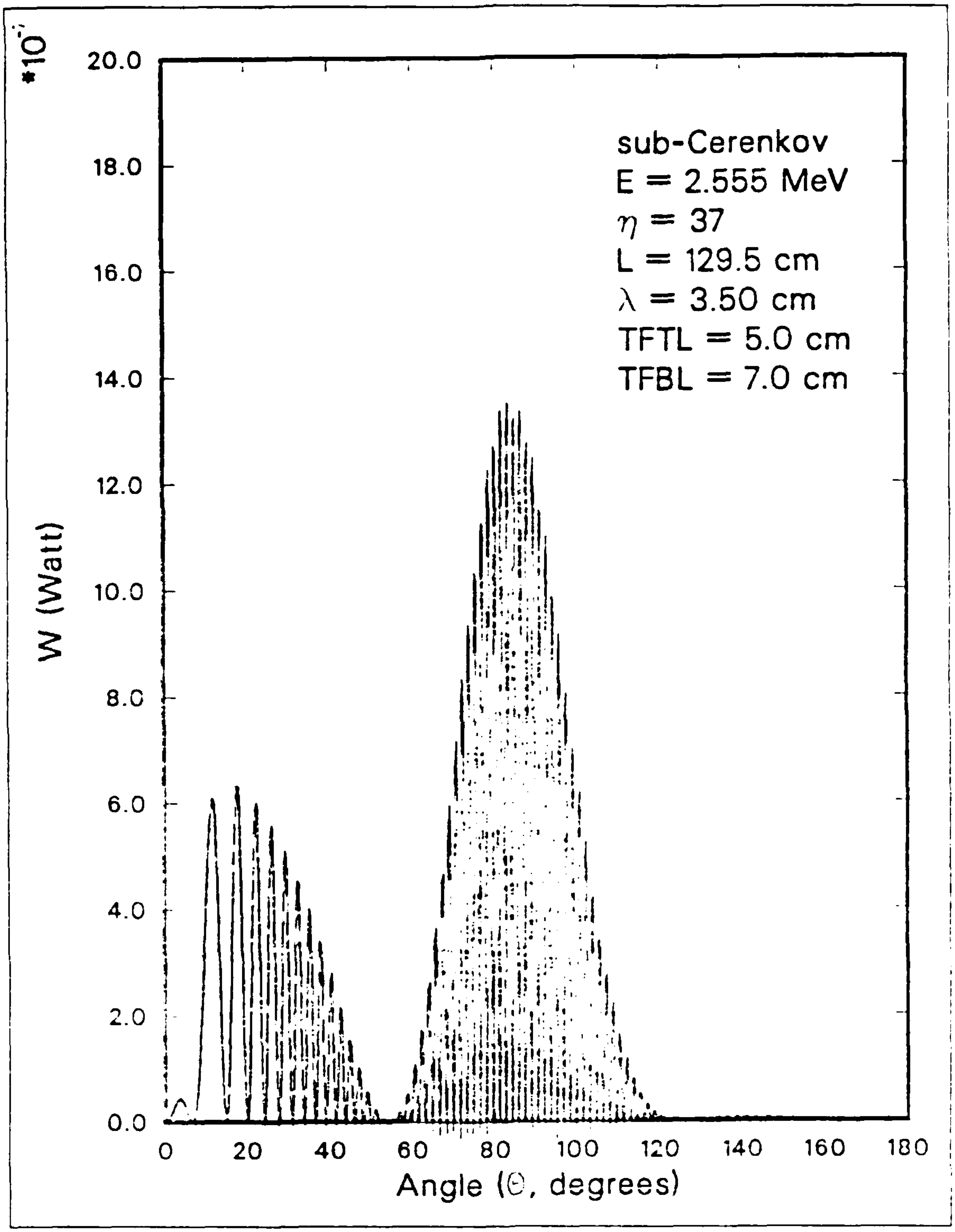


Fig. 3.31 Trapezoidal Function with $\ell/\lambda = 1.71$, $l/\lambda = 0.29$

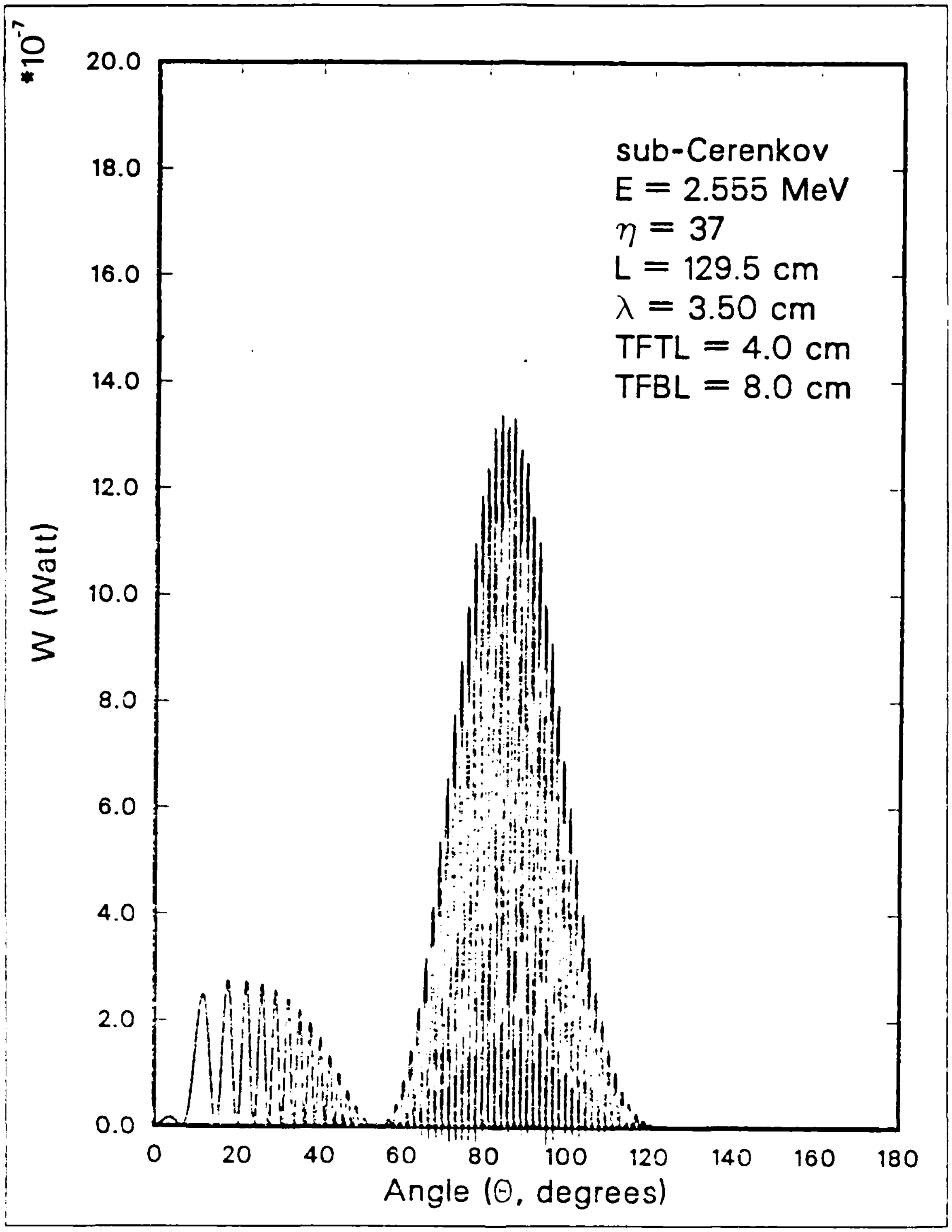


Fig. 3.32 Trapezoidal Function with ℓ/λ = 1.71, l/λ = 0.57

The last figure of the $\eta = 12$ series is drawn for both ℓ/λ and $1/\lambda$ greater than one. Consequently one would expect the radiation envelope to display both terms in the form factors for a trapezoidal charge distribution. That it apparently does not may be due to the fact that the lengths chosen in order to achieve these make for a charge distribution which is almost triangular.

Figures 3.30–3.32 are calculated for the below threshold condition of $\eta = 37$. All have ℓ/λ greater than one and $1/\lambda$ less than one. As with other figures with this value of η, the envelope is more evident.

When both values of ℓ/λ and $1/\lambda$ increase the peak values decrease mainly in the region of angles between 0^o and approximately 55^o and the radiation intensity is enhanced around 90^o. It is difficult to determine the development of the radiation pattern with respect to ℓ/λ and $1/\lambda$ because both values can change the radiation pattern at same time. To analyze the radiation pattern in another way the angle where zeros happen can be investigated by calculation. Let's set:

$$\frac{k_z \ell}{2} = n\,\pi\,, \qquad \frac{k_z 1}{2} = m\,\pi \tag{3.1}$$

where $k_z = k \cos\theta$, and m,n are integers. Substituting for k_z gives

$$\cos\theta_n = \pm\, n \frac{\lambda}{\ell}\,, \qquad \cos\theta_m = \pm\, m \frac{\lambda}{1} \tag{3.2}$$

If as in most cases considered here $\frac{1}{\lambda} < 1$, these are no solutions for θ_m.

Thus only the solutions for θ_n are considered below. A example is Fig. 3.25 where $\frac{\ell}{\lambda} = 1.71$, $\ell = 6$ cm, $\lambda = 3.5$ cm.

$$\cos\theta = \pm n \frac{3.5}{6} = \pm n \frac{1}{1.71} = \pm n \times 0.58 \qquad (3.3)$$

The solutions are for θ_n are

$$\theta_1 = 54.5^o \text{ and } \theta_{-1} = 125.5^o. \qquad (3.4)$$

which agree with the figure. These values also apply to Fig. 3.26, Fig. 3.27, Fig. 3.31, and Fig. 3.32 which have the same ratio of $\frac{\ell}{\lambda}$.

In Fig. 3.29 where $\frac{\ell}{\lambda}$ 1.29, $l/\lambda = 1.27$,

$$\cos\theta_n = \pm n \frac{1}{1.29}, \qquad \cos\theta_m = \pm m \frac{1}{1.27} \qquad (3.5)$$

The solutions are $\theta_1 = 39.2^o$, $\theta_{-1} = 129.2^o$ for θ_n and $\theta_1 = 38^o$, $\theta_{-1} = 128^o$. In This case the zeros for θ_m and θ_n are so close together as to be indistinguishable in the figure.

IV. CONCLUSIONS AND RECOMMENDATIONS

The object of this work is to assess the effects of the charge distribution of a bunch on the sub–Cerenkov radiation from a charged particle beam, specifically investigating the short beam path region at energies above and below the threshold. It contains many calculated radiation patterns for the three kinds of charge distributions.

With the charge distribution of Gaussian function, the radiation intensity envelope near 90^o represents the square of the bunch form factor $F(\mathbf{k})$ when the bunch length is larger than a half of the wavelength. When the bunch length is about same as the wavelength or larger than that of the level charge distribution the radiation pattern around 90^o is also dominated by the square of the bunch form factor $F(\mathbf{k})$.

It is difficult to determine the characteristics of the radiation pattern on the trapezoidal function by the ratio of bunch length to wavelength because the level top length and level base length can change the shape of radiation pattern at same time. However the radiation pattern of the trapezoidal function can be partially characterized by analyzing the zeros of the curves.

A summary of results is :

1. When the bunch length is much smaller than the wavelength of the emitted radiation, the radiation pattern is characteristic of point charge.
2. When η is increased the total radiation pattern does not change except for minor differences in the frequency of oscillation.

3. When the wavelength of the emitted radiation is comparable to or larger than the bunch length, a significant amount of radiation appears at near 90° to the beam.

4. The envelope of the 90° radiation is the square of the bunch form factor. This envelope is skewed slightly as a result of monotonic character of the geometrical envelope function.

To enhance this preliminary work the following is recommanded:

1. Investigate the behavior of the square of form factor F(**k**) only when the bunch length varies. This will give the insight into the behavior of radiation pattern.

2. Determine why varying the top length of the trapezoidal pulse shape causes significant enhancement of the forward lobe envelope.

3. Determine the effects of changes in beam energy, pulse width,pulse frequency, and path length.

4. Confirm the results found by mapping the microwave radiation measured at a comparable particle accelerator.

The examples presented here are idealized and there has been no attempt to take into consideration such factors as beam pulse erosion as it transverses the atmosphere and the ground plane reflection in interference[Ref. 4: p.1996]. But the complete angular map of the envelope of the radiation pattern could provide a measure of $F(\mathbf{k_z})$ and an excellent reference to establish a method of determining the beam pulse charge distribution based on sub–Cerenkov radiation patterns.

APPENDIX A

PROGRAM FOR CALCULATION OF RADIATED POWER

```
*********************************************************************
* THIS PROGRAM IS TO CALCULATE THE POWER PER UNIT SOLID ANGLE RADIA- *
* TED AT THE FREQUENCY NU. IT WAS ORIGINALLY DEVELOPED BY PROFESSOR  *
* JOHN R. NEIGHBOURS AND OTHERS FOR TECTRONIX COMPUTER. THIS AUTHOR  *
* MODIFIED TO RUN ON IBM 370 MAINFRAME COMPUTER IN DEC. 1987.        *
* THE THEORY AND ALL EQUATION ARE WELL GIVEN IN REF. 5.              *
*********************************************************************

      PROGRAM JNN
      COMMON /VA/HH,HU,SDXX /DOUPA/L,ETA,TMAX,DT,E,N,B,LL,RR,NN,RFTL,
     +                  RFBL,TFTL,TFBL,TRIBL,NBETA
      DOUBLE PRECISION  C,C0,MU0,NU0,Q,PI,E0,E,NBETA,
      DOUBLE PRECISION  TMAX,DT,NU,L,ETA,N,B,LL,RR,NN
      DOUBLE PRECISION  IIMAX,KK,CONST,WMAX,THETA,W,T,KKZ,H,DENOM1,
      DOUBLE PRECISION  DENOM2,K0
      DOUBLE PRECISION  GAMMA,V,U,II,R,HA,HB,HC,HD,DD,DEXIN
      DOUBLE PRECISION  RFTL,RFBL,TFTL,TFBL,TRIBL
      DOUBLE PRECISION  DENOM3,DENOM4,DENOM5,DENOM6,DENOM7,DENOM8,
      DOUBLE PRECISION  HE,HF,HG,HI
      DOUBLE PRECISION  HJ,HK,HL,Z,LI,LIN,HX,HW,KE,SDXX
      REAL  XWMAX,XTHETA,XW,YMAX,SDYY,SDY,JX,JYY,YY,YNUM,X,Y,SDX,
     +      XX ,XNUM,RTMAX,RSDXX,RWMAX,RTHETA,RW
      REAL  REL,REE,REN,REB,RELL,RERR,RENN,DELTA
      REAL  RERFTL,RERFBL,RETFTL,RETFBL,RETRIB,REHU
      INTEGER  I,K,KMAX,IMAX,HH,J,JXMAX,JYMAX,IPA,P,HU
      CHARACTER*1  PARACH,EXPPTS,EXPTCH,SAVEQ,PPRE,CHANGE,ANS,AXCH,
     +             ANS2,ANS3
      CHARACTER*13 NAMEPF,NAMEWF,NAMEEX
      DIMENSION  XTHETA(1:100)
      DIMENSION  XW(1:100)
      DIMENSION  THETA(0:4500)
      DIMENSION  W(0:4500)
      DIMENSION  H(1:7)
C
C     * ASSIGNMENT OF CONSTANTS
C
        C=2.997122D08
        C0=2.997925D08
        MU0=1.2566437061D-06
C
C  ********** TO VARY CHARGE  ************
C
        PI=3.1415926535897932D0
```

```
        E0=0.5117D0
C
5     PRINT*, '           '
      PRINT*, ' ENTER BUNCH CHARGE.(DEFAULT= 1.5E-12) '
      READ*, Q
      IF(Q.GT.0) GO TO 45
      Q=1.5D-12
45    PRINT*, ' ENTER FUNDAMENTAL FREQUNCY NU0. (DEFAULT= 2.85E9)'
      READ*, NU0
      IF(NU0.GT.0) GO TO 55
      NU0=2.85D09
55    CONTINUE
C
      PRINT*,'THE INDEX OF REFRACTION IN THE AIR IS 1.000268(DEFAULT).'0
      PRINT*,'DO YOU WISH TO CHANGE? (Y/N) '
      READ '(1A)', ANS2
      IF(ANS2.EQ.'Y') THEN
        PRINT*,'ENTER THEINDEX OF REFRACTION.  '
        READ*, DEXIN
      ELSE
       DEXIN=1.000268D0
      END IF
      C=C0/DEXIN
C
C    *******   DECISION OF PARAMETER FILE*******
C
      PRINT *
      PRINT *, '     1: CREATE NEW PARAMETER FILE'
      PRINT *, '     2: USE OLD FILE'
      PRINT *, '     3: EXIT'
      PRINT *
      PRINT *,'       ENTER YOUR CHOICE :'
      READ '(1A)', PARACH
      IF(PARACH.EQ.'3') GOTO 700
      IF(PARACH.EQ.'2') CALL INAMPF
      IF(PARACH.EQ.'1')  CALL MAKEPF
C
*****************************************************
*         READ IN ALL PARAMETERS FROM EXTERNAL      *
*              FILE/PRINTOUT PARAMETERS             *
*****************************************************
C
99    WRITE(6,100)
100   FORMAT(///'THE PARAMETERS YOU ENTERED ARE:')
      REWIND 1
120   READ(1,*) HH
131   WRITE(6,135) HH
135   FORMAT(/'FOURIER TRANSFORM CHOICE :    ',I8)
      IF (HH.NE.1) GOTO 137
      WRITE (6,136)
136   FORMAT(/,37X,'GAUSSIAN FUNCTION ' )
137   IF (HH.NE.2) GOTO 139
```

```
      WRITE (6,138)
138   FORMAT (/,37X,'LEVEL FUNCTION ' )
139   IF (HH.NE.3) GOTO 141
      WRITE (6,140)
140   FORMAT (/'SUM OF LEVEL AND RIPPLE FUNCTIONS' )
141   IF (HH.NE.4) GOTO 143
      WRITE (6,142)
142   FORMAT(/'MULTIPLE HUMP FUNCTION' )
143   IF (HH.NE.5) GOTO 145
      WRITE (6,144)
144   FORMAT (/'ROUNDED FUNCTION' )
145   IF (HH.NE.6) GOTO 147
      WRITE (6,146)
146   FORMAT (/'TRAPEZOIDAL FUNCTION' )
147   IF (HH.NE.7) GOTO 149
      WRITE (6,148)
148   FORMAT (/'TRIANGLE FUNCTION' )
C
149   READ(1,*) ETA
9151  WRITE(6,151) ETA
151   FORMAT(/'   ETA (L/RAMMDA) :                 ',D16.4)
      READ(1,*) TMAX
154   WRITE(6,155) TMAX
155   FORMAT(/'   MAXIMUM THETA VALUE :            ',D16.4)
      READ(1,*) DT
164   WRITE(6,165) DT
165   FORMAT(/'   THETA CALCULATION INCREMENT :',D16.4)
      READ(1,*) SDXX
174   WRITE(6,175) SDXX
175   FORMAT(/'   THETA MARKING INCREMENT :        ',D16.4)
C     READ(1,*) E
      READ(1,*) NBETA
C184   WRITE(6,185) E
184   WRITE(6,185) NBETA
C185   FORMAT(/'   BEAM ENERGY :                   ',D16.4)
185   FORMAT(/'   VALUE OF NBETA :                  ',D16.4)
      READ(1,*) N
194   WRITE(6,195) N
195   FORMAT(/'   HARMONIC NUMBER :                ',D16.4)
C
C
      IF (HH.NE.1) GOTO 206
C
      READ(1,*) B
204   WRITE(6,205) B
205   FORMAT(/'   BUNCH LENGTH (M) :                   ',D16.4)
C
206   IF (HH.LT.2) GOTO 216
      IF (HH.GT.4) GOTO 216
C
      READ(1,*) LL
214   WRITE(6,215) LL
```

```
215   FORMAT(/'   LEVEL FUNCTION LENGTH (M) :      ',D16.4)
C
216   IF (HH.NE.3) GOTO 9235
C
      READ(1,*) RR
224   WRITE(6,225) RR
225   FORMAT(/'   FOURIER RATIO CONSTANT :     ',D16.4)
C
C
      READ(1,*) NN
234   WRITE(6,235) NN
235   FORMAT(/'   NUMBER OF RIPPLES :          ',D16.4)
C
9235  IF (HH.NE.4) GOTO 236
C
      READ (1,*)HU
9237  WRITE (6,9239) HU
9239  FORMAT(/'   NUMBER OF HUMPS  :           ',I4)
C
236   IF (HH.NE.5) GOTO 241
C
      READ (1,*) RFTL
9238  WRITE (6,238) RFTL
238   FORMAT (/'   ROUNDED FUNCTION LEVEL TOP LENGTH :    ',D16.4)
C
      READ (1,*) RFBL
9240  WRITE (6,240) RFBL
240   FORMAT (/'   ROUNDED FUNCTION BASE LENGTH :         ',D16.4)
C
241   IF (HH.NE.6) GOTO 246
C
      READ (1,*) TFTL
9243  WRITE (6,243)TFTL
243   FORMAT (/'   TRAPEZOIDAL FUNCTION TOP LEVEL LENGTH :',D16.4)
C
      READ (1,*) TFBL
9245  WRITE (6,245)TFBL
245   FORMAT (/'   TRAPEZOIDAL FUNCTION BASE LENGTH :     ',D16.4)
C
246   IF (HH.NE.7) GOTO 249
C
      READ (1,*) TRIBL
9248  WRITE (6,248)TRIBL
248   FORMAT (/'   TRIANGLE FUNCTION BASE LENGTH :        ',D16.4)
249   WRITE(6,250)
250   FORMAT(//'DO YOU WISH TO CHANGE ANY OF THESE ?(Y OR N)')
      READ'(A1)', CHANGE
C
      IF(CHANGE.EQ.'Y') GO TO 700
C
******************************
* ***  BEGIN CALCULATION ***  *
```

```
*******************************
C
325   IIMAX=TMAX/DT
      IMAX=INT(IIMAX)
      NU=N*NU0
      IF ((HH.GE.2).AND.(HH.LE.4)) THEN
        DD=LL/2.0D0
      END IF
C
      KK=2.0D0*PI*NU/C
      CONST=MU0*C*(NU0**2.0)*(Q**2.0)/(8.0D0*(PI**2.0))
      WMAX=0.0D0
      DO 350 I=0,IMAX
        THETA(I)=DBLE(I)*DT
        T=PI*THETA(I)/180.0D0
        KKZ=KK*DCOS(T)
C
        IF (HH.NE.1) GOTO 326
C
        H(1)=DEXP(-1.0D0*((KKZ*B/2.0D0)**2.0))
C
326     CONTINUE
        IF (HH.LT.2) GOTO 328
        IF (HH.GT.3) GOTO 328
C
        DENOM1=KKZ*DD
        IF (DENOM1.EQ.0) GOTO 327
        H(2)=(DSIN (KKZ*DD))/(KKZ*DD)
        GOTO 328
327     H(2)=0.0D0
C
328     IF(HH.NE.3) GOTO 333
C
        KO=PI*NN/DD
        DENOM2=(KKZ-KO)*DD
C
        IF(DENOM2.EQ.0) GOTO 329
C
        HA= DSIN(DENOM2)/DENOM2
C
        GOTO 330
C
329     HA=0.0D0
330     DENOM3=(KKZ+KO)*DD
C
        IF (DENOM3.EQ.0) GOTO 331
C
        HB=DSIN(DENOM3)/DENOM3
C
        GOTO 332
C
331     HB=0.0D0
```

```
332     H(3)=H(2)+((RR/2.0D0)*(HA+HB))
C
333     IF(HH.NE.4) GOTO 335
C
        Z=(KKZ*DD)
C
        IF(Z.EQ.0) GOTO 334
C
        H(4)=1.0D0*((DSIN(Z))/Z)
        DENOM4= 1.0
        DO 9333 P=1,HU
          KE=(2.0D0*DBLE(P))-1.0D0
          LI=((2.0D0*DBLE(HU))-KE)/((2.0D0*DBLE(HU))-1.0D0)
          LIN=((-1.0D0)**DBLE(P))*(-1.0D0)
          HX=(LIN*LI*DSIN(Z*LI))/(Z*LI)
          HW=LIN*LI
          H(4)=H(4)+HX
          DENOM4= DENOM4+HW
9333    CONTINUE
        H(4)=H(4)/DENOM4
C
        GOTO 335
C
334     H(4)=0.0D0
C
335     IF (HH.NE.5) GO TO 339
C
        HL=(8D0*16D0)/(((RFBL-RFTL)**2.0)*(KKZ**3)*(RFBL+RFTL))
        HG=HL*DSIN((KKZ/4.0D0)*(RFBL+RFTL))
        HJ= (RFTL*DSIN(KKZ*RFTL/2.0D0))/(KKZ*RFTL/2.0D0)
        HK= (RFBL*DSIN(KKZ*RFBL/2.0D0))/(KKZ*RFBL/2.0D0)
        HI=(32D0/((((RFBL-RFTL)*(KKZ))**2.0)*(RFTL+RFBL)))*(HJ+HK)
        H(5)=HG-HI
C
339     IF (HH.NE.6) GOTO 345
C
        DENOM6=KKZ*(TFBL+TFTL)/4.0D0
        DENOM7=KKZ*(TFBL-TFTL)/4.0D0
        HE=DSIN(DENOM6)/DENOM6
        HF=DSIN(DENOM7)/DENOM7
        H(6)=(TFBL+TFTL)/2.0D0*HE*HF
C
345     IF(HH.NE.7) GOTO 349
C
        DENOM5=(KKZ*TRIBL)/4.0D0
C
        IF (DENOM5.EQ.0) GOTO 346
        H(7) = (DSIN(DENOM5)/(DENOM5))**2.0
C
        GOTO 349
C
346     H(7)=0.0D0
```

```
C
349     CONTINUE
C
C       GAMMA=E/E0
        L=ETA*C/NU
C       GAMMA=DSQRT(1.0D0/(1.0D0-(NBETA/DEXIN)**2))
C       V=C0*(DSQRT(1.0D0-(1.0D0/(GAMMA**2.0))))
        V=C0*(NBETA/DEXIN)
        U=(KK*L/2.0D0)*((C/V)-DCOS(T))
        II=DSIN(U)/U
        R=KK*L*H(HH)*II*DSIN(T)
        W(I)=CONST*(R**2.0)
C
C  *** CALCULATION OF MAXIMUM W ***
C
272     WMAX=DMAX1(WMAX,W(I))
C
350   CONTINUE
C
C  ******  DECISION TO SAVE VALUES CALCULATED  ******
C
      WRITE(6,360)
360   FORMAT(/'DO WANT TO SAVE THE RESULTS IN A FILE? (Y/N)' )
      READ'(A1)', SAVEQ
C
      IF(SAVEQ.EQ.'N') GOTO 440
C
      PRINT *, 'UNDER WHAT FILE NAME? '
      READ '(A10)', NAMEWF
      OPEN(UNIT=3,FILE=NAMEWF,STATUS='NEW',FORM='FORMATTED')
      DO 370 I=0,IMAX
        RTHETA=REAL(THETA(I))
        RW=REAL(W(I))
        WRITE(3,380) RTHETA,RW
380     FORMAT(4X,F8.3,2X,F20.18)
370   CONTINUE
      WRITE(3,385)
385   FORMAT(7X,'0.000')
      WRITE(3,390) WMAX
390   FORMAT(2X,'WMAX = ',D16.4)
      WRITE(3,392) ETA
392   FORMAT(2X,'ETA = ',D16.4)
      WRITE(3,394) NBETA
394   FORMAT(2X,'NBETA = ',D16.4)
C     WRITE(3,396) B
C396   FORMAT(2X,'BUNCH LENGTH = ',D16.4)
C
C  ******  DECISION TO PRINTOUT,RE-RUN,OR EXIT  ******
C
440   WRITE(6,445)
445   FORMAT(////'     1: PRINT OUT VALUES',/
     +           '     2: RUN PROGRAM AGAIN',/
```

```
     +              '    3: EXIT',///
     +              '   ENTER CHOICE.___')
      READ'(A1)', PPRE
C
      IF(PPRE.EQ.'1') GOTO 660
      IF(PPRE.EQ.'2') GOTO 05
      IF(PPRE.EQ.'3') GOTO 700
      GOTO 440
C
C  *** PRINT OUT VALUES ***
C
660   WRITE(6,670)
670   FORMAT('    THETA              W'/23('-')/)
      DO 690 I=0,IMAX
        WRITE(6,680) THETA(I),W(I)
680     FORMAT(F8.2,F15.4)
690   CONTINUE
C
C ********* PROGRAM ENDS **********************************
700        END
C
C
C
*****************************
* *** SUBROUTINE INAMPF *** *
*****************************
C
      SUBROUTINE INAMPF
C
C  *** INPUT OLD PARAMETER FILE NAME
      CHARACTER*10 NAMEPF
      WRITE(6,900)
900   FORMAT(/'ENTER THE NAME OF THE PARAMETER FILE YOU WISH TO',
     +       ' USE(MAX 10 CHAR)   ' )
      READ'(A10)', NAMEPF
      WRITE(6,911)
911   FORMAT(/'TEST LINE ONE' )
      OPEN(UNIT=1,FILE=NAMEPF,STATUS='OLD',FORM='FORMATTED',
     +     BLANK='NULL' )
      WRITE(6,912)
912   FORMAT(/'TEST LINE TWO' )
      RETURN
      END
C
*****************************
* *** SUBROUTINE INAMEX *** *
*****************************
C
      SUBROUTINE INAMEX
C
C  *** INPUT OLD EXPERIMENTAL POINTS FILE NAME ***
      CHARACTER*10 NAMEEX
```

```
      WRITE(6,1000)
1000  FORMAT(/'ENTER NAME OF EXPERIMENTAL POINTS FILE YOU WISH',
     +        'TO USE(MAX 10 CHAR)  ' )
      READ'(A10)', NAMEEX
      OPEN(UNIT=2,FILE=NAMEEX,STATUS='OLD',FORM='FORMATTED',
     +     BLANK='NULL' )
      RETURN
      END
C
C
******************************
* *** SUBROUTINE MAKEPF *** *
******************************
C
      SUBROUTINE MAKEPF
C
C     *** INPUT OF PARAMETERS INTO NEW FILE (UNIT=1)***
C
      COMMON /VA/HH,HU,SDXX /DOUPA/L,ETA,TMAX,DT,E,N,B,LL,RR,NN,RFTL,
     +        RFBL,TFTL,TFBL,TRIBL,NBETA
      DOUBLE PRECISION L,ETA,TMAX,DT,E,N,B,LL,SDXX,NBETA,
     +        RR,NN,RFTL,RFBL,TFTL,TFBL,TRIBL
      INTEGER HH,HU
      CHARACTER*10 NAMEPF
      WRITE(6,1300)
1300  FORMAT(/'ENTER THE NAME FOR THE NEW PARAMETER FILE.',
     +        '(MAX 10 CHAR) ' )
      READ'(A10)', NAMEPF
      OPEN(UNIT=1,FILE=NAMEPF,STATUS='NEW',FORM='FORMATTED',
     +     ACCESS='SEQUENTIAL',BLANK='NULL')
      PRINT*, '     '
      WRITE(6,1320)
1320  FORMAT(/////'NOTE: ALL THE PARAMETERS MUST BE ENTERED',
     +        ' ALTHOUGH SOME MAY NOT BE USED')
      WRITE(6,1330)
1330  FORMAT(/'     1: GAUSSIAN FUNCTION'/'     2: LEVEL FUNCTION',
     +        /'     3: SUM OF LEVEL AND RIPPLE FUNCTIONS',
     +        /'     4: MULTIPLE HUMP FUNCTION',
     +        /'     5: ROUNDED FUNCTION',
     +        /'     6: TRAPEZOID FUNCTION',
     +        /'     7: TRIANGLE FUNCTION')
      WRITE(6,1340)
1340  FORMAT(/'ENTER THE FOURIERTRANSFORM CHOICE:')
      READ*, HH
C
1356  IF(HH.LE.7) GO TO 1359
C
      WRITE(6,1357)
1357  FORMAT('     FOURIER TRANSFORM CHOICE NOT DEFINED.'///,
     +        '                ENTER NEW CHOICE:')
      READ*, HH
C
```

```
      GO TO 1356
C
1359  WRITE(1,*) HH
      WRITE(6,1370)
1370  FORMAT(/'ENTER ETA (L/RAMMDA). ( DEFAULT = 12.0D-2 ) ' )
      READ*, ETA
      IF(ETA.GT.0.0) GOTO 1385
      ETA=12.0D0
1385  WRITE(1,*) ETA
      WRITE(6,1400)
1400  FORMAT(/'ENTER THE MAXIMUM VALUE OF THETA TO BE',
     +        ' CALCULATED(DEG).'/'      ( DEFAULT = 45.0 ')
      READ*, TMAX
      IF(TMAX.GT.0.0) GOTO 1415
      TMAX=45.0D0
1415  WRITE(1,*) TMAX
      WRITE(6,1430)
1430  FORMAT(/'ENTER THE ANGLE CALCULATION INCREMENT(DEG)',
     +        '(DEFAULT=0.1)  ' )
      READ*, DT
      IF(DT.GT.0.0) GOTO 1445
      DT=0.10D0
1445  WRITE(1,*) DT
      WRITE(6,1460)
1460  FORMAT(/'ENTER THE ANGLE MARKING INCREMENT(DEG)',
     +        ' (DEFAULT=15.0)  ' )
      READ*, SDXX
      IF(SDXX.GT.0.0) GOTO 1475
      SDXX=15.0D0
1475  WRITE(1,*) SDXX
      WRITE(6,1490)
C1490  FORMAT(/'ENTER THE BEAM ENERGY (MEV) (DEFAULT=100.0) ' )
1490  FORMAT(/'ENTER THE VALUE OF NBETA (DEFAULT=0.98) ' )
C     READ*, E
      READ*, NBETA
C     IF(E.GT.0.0) GOTO 1505
      IF(NBETA.GT.0.0) GOTO 1505
C     E=100.0D0
      E=0.98D0
C1505  WRITE(1,*) E
1505  WRITE(1,*) NBETA
      WRITE(6,1520)
1520  FORMAT(/'ENTER THE HARMONIC NUMBER (DEFAULT=1.0) ' )
      READ*, N
      IF(N.GT.0.0) GOTO 1535
      N=1.0D0
1535  WRITE(1,*) N
C
      IF (HH.NE.1) GOTO 1575
C
      WRITE(6,1550)
1550  FORMAT(/'ENTER THE BUNCH LENGTH (M).( DEFAULT = 0.24D-2 ) ' )
```

```
      READ*, B
C
      IF(B.GT.Ø.Ø) GOTO 1565
C
      B=Ø.24DØ
1565  WRITE(1,*) B
C
1575  IF ((HH.LT.2).OR.(HH.GT.4)) GOTO 16Ø5
C
      WRITE(6,158Ø)
158Ø  FORMAT(/'ENTER THE LEVEL FUNCTION LENGTH (M).',
     +        ' (DEFAULT=Ø.Ø1) ' )
      READ*, LL
C
         IF(LL.GT.Ø.Ø) GOTO 1595
C
         LL=Ø.Ø1DØ
1595     WRITE(1,*) LL
C
16Ø5     IF (HH.NE.3) GOTO 1635
C
      WRITE(6,161Ø)
161Ø  FORMAT(////'ENTER THE FOURIER RATIO CONSTANT (DEFAULT=1.Ø).')
      READ*, RR
C
      IF(RR.GT.Ø.Ø) GOTO 1625
C
      RR=1.ØDØ
1625  WRITE(1,*) RR
C
1635  IF (HH.NE.3) GOTO 1665
C
      WRITE(6,164Ø)
164Ø  FORMAT(/'ENTER THE NUMBER OF RIPPLES (DEFAULT=1.Ø)   ' )
      READ*, NN
C
      IF(NN.GT.Ø.Ø) GOTO 1655
C
      NN=1.ØØØØ
1655  WRITE(1,*) NN
C
1665  IF (HH.NE.4) GOTO 17ØØ
C
      WRITE(6,167Ø)
167Ø  FORMAT(/'ENTER NUMBER OF HUMPS (DEFAULT=2)   ' )
      READ*, HU
C
      IF(HU.GT.2) GOTO 168Ø
C
      HU=2
168Ø  WRITE(1,*)HU
C
```

```
1700  IF (HH.NE.5) GOTO 1800
C
      WRITE (6,1710)
1710  FORMAT(/'ENTER THE ROUNDED FUNCTION LEVEL TOP LENGTH (CM)',
     +        /'       (DEFAULT = 1.0) ' )
      READ*, RFTL
C
      IF (RFTL.GT.0.0) GOTO 1730
C
      RFTL = 1.0D0
1730  WRITE (1,*) RFTL
      WRITE (6,1760)
1760  FORMAT (/'ENTER THE ROUNDED FUNCTION BASE LENGTH (CM).'/,
     +         '        (DEFAULT = 2.0) ' )
      READ*, RFBL
C
      IF (RFBL.GT.0.0) GOTO 1780
C
      RFBL = 1.0D0
1780  WRITE (1,*) RFBL
C
1800  IF (HH.NE.6) GOTO 1900
C
      WRITE (6,1810)
1810  FORMAT (/'ENTER THE TRAPEZOIDAL FUNCTION LEVEL TOP',
     +         'LENGTH (CM).'/'      (DEFAULT = 1.0)' )
      READ*, TFTL
C
      IF (TFTL.GT.0.0) GOTO 1830
C
      TFTL = 1.0D0
1830  WRITE (1,*) TFTL
      WRITE (6,1860)
1860  FORMAT (/'ENTER THE TRAPEZOIDAL FUNCTION BASE LENGTH (CM)',
     +         /'       (DEFAULT = 2.0) ' )
      READ*, TFBL
C
      IF (TFBL.GT.0.0) GOTO 1880
C
      TFBL = 1.0
1880  WRITE (1,*) TFBL
C
1900  IF (HH.NE.7) GOTO 1990
C
      WRITE (6,1910)
1910  FORMAT (/'ENTER TRAIANGLE FUNCTION BASE LENGTH (CM).'//,
     +         '       (DEFAULT = 1.0) ' )
      READ*, TRIBL
C
      IF (TRIBL.GT.0.0) GOTO 1930
C
      TRIBL = 1.0D0
```

```
1930  WRITE (1,*) TRIBL
      WRITE (6,1941)
1941  FORMAT(/'TEST LINE THREE' )
C
1990  ENDFILE 1
C
      WRITE(6,1991)
1991  FORMAT(/'TEST LINE FOUR' )
      RETURN
      END
C
```

APPENDIX B

PROGRAM FOR PLOTTING THE RADIATION PATTERN

```
***********************************************************************
* THIS PROGRAM IS TO PLOT THE POWER PER UNIT SOLID ANGLE RADIATED     *
* AT THE FREQUENCY NU. THE THEORY AND ALL EQUATIONS ARE DESCRIBED     *
* IN REF.3. IT ASSUMES THETA IN COL. 1 (DEGREES) AND POWER IN COL. 2 *
* (WATT) RESPECTIVELY. IT SUPPORTS A SINGLE PLOT OF MULTIPLE CURVES   *
* AND USES THE COMPRS/DISSPOP OPTION OF DISSPLA.                      *
***********************************************************************
C
      REAL YX,XMIN,XMAX,YMIN,YMAX,X,Y,DX,AX,AY,XPHY,YPHY
      INTEGER IOUT,ITICK,ITICKX,ITICKY,IYVAR,ICT,INN,NB,NETA,NF,
     +        NBL,LF,NMOD,NRAM,TLL,BL,NL
      CHARACTER*1 YES,ANS
      CHARACTER*4 BLNK(2)
      CHARACTER*60 IMESS,IPHI,IRAM,IMOD,INB,IBL,IETA,LFL,INF,ITLL,
     +             INL
C
      DIMENSION X(2000),Y(2000)
      DIMENSION YX(1:5000,1:2)
C
      DATA YES/'Y'/
      DATA BLNK/'    ','    '/
       EPS=.001
C
C          INITIALISE PLOTTER
C
  100 CONTINUE
 9400 FORMAT(A1)
 9401 FORMAT(I1)
 9402 FORMAT(I2)
      WRITE(4,9403)
 9403 FORMAT(' DO YOU WANT:',/,
     X       '      1. COMPRES',/,
     X       '      2. TEK618',/,
     X       ' ENTER NUMBER (I1)',/)
      READ(4,*) IOUT
      IF(IOUT.EQ.1) THEN
         CALL COMPRS
      ELSEIF(IOUT.EQ.2) THEN
         CALL TEK618
      ENDIF
      AX = 4.6810
      AY = 6.7416
```

```
      CALL HWROT('MOVIE')
      CALL PAGE(8.5,11.Ø)
      XPHY=2.Ø84Ø
      YPHY=2.7953
C
C   DEFINE: LOWER/UPPER CASE STD AND GREEK SHIFT LABELS (+,!,?,%),
C   SHIFT FOR INSTRUCTION SET(&), AND THE TYPE FACE.
C
      CALL MX1ALF('STANDARD','!')
      CALL MX2ALF('L/CSTD','+')
      CALL MX3ALF('GREEK','?')
      CALL MX4ALF('L/CGREEK','%')
      CALL MX5ALF('INSTRU','&')
      CALL SWISSL
      CALL SHDCHR(9Ø.,1,Ø.ØØ2,1)
 941Ø FORMAT(D16.8)
      CALL HEIGHT(Ø.14)
      CALL PHYSOR(XPH[illegible]HY)
      CALL AREA2D(AX,AY)
C
C        CLOSE GRAPH AND REOPEN FOR LABEL AXES NUMBER TYPES
C
      CALL ENDGR(Ø)
      CALL PHYSOR(XPHY,YPHY)
      CALL AREA2D(AX,AY)
      CALL XNONUM
C
C        DETERMINE THE AXIS LABELS:
C
C        X-AXIS LABEL AND NUMBER TYPE
C
      CALL EXCMS('CLRSCRN')
      WRITE(4,9415)
 9415 FORMAT(' DO YOU WANT INTEGERS ON THE X-AXIS? (Y/N)',/)
      READ(4,94ØØ) ANS
      IF(ANS.EQ.YES) CALL XINTAX
      CALL XNAME('A+NGLE! (?Q!, +DEGREES!)$',1ØØ)
C
C        Y-AXIS LABEL AND NUMBER TYPE
C
      WRITE(4,9417)
 9417 FORMAT(' CHOOSE THE Y VARIABLE TO BE PLOTTED (I1):',/,
     X       '       1 ---------      W (WATT)  ',/,
     X       '       2 ---------      DJ      ',/)
      READ(4,*) IYVAR
      IF (IYVAR.EQ.2) THEN
          CALL YNAME('D+J          !$',1ØØ)
      ELSE
          CALL YNAME('W (W+ATT!)$',1ØØ)
      ENDIF
C
C  ROTATE NUMBERS ON Y-AXIS AND REVERSE TICKS
```

```
C
      CALL YAXANG(0.)
      CALL XREVTK
      CALL YREVTK
      WRITE(4,7900)
 7900 FORMAT(' INPUT YMIN OF THE FIRST SUBPLOT (F16.8):',/)
      READ(4,*) YMIN
      CALL YAXEND ('NOLAST')
      YMAX=YMIN+.1
      CALL GRAF(0.,1.,1.,YMIN,YMAX,.1)
      CALL THKFRM(.027)
      CALL FRAME
      CALL ENDGR(0)
C
C       CLOSED GRAF FOR AXIS LABELS, NOW REOPEN TO PLOT
C
      CALL PHYSOR(XPHY,YPHY)
      CALL AREA2D(AX,AY)
      CALL RESET ('YAXEND')
      CALL RESET ('XNONUM')
      CALL YNAME(BLNK,2)
      CALL XNAME(BLNK,2)
      CALL ENDGR(0)
C
C       POSITION OR REPOSITION ORIGIN AND SCALE PLOT
C
      CALL PHYSOR(XPHY,YPHY)
      CALL AREA2D(AX,AY)
      CALL RESET ('YAXEND')
      CALL YAXEND('NOFIRST')
C
C      DEFINE COORDINATE SYSTEM
C      KEEP OR CHANGE CONSTANTS
C
      CALL EXCMS('CLRSCRN')
      WRITE(4,9423)
 9423 FORMAT(' INPUT XMIN: (F16.8)')
      READ(4,*) XMIN
      WRITE(4,9424)
 9424 FORMAT(' INPUT XSTEP: (F16.8)')
      READ(4,*) XSTEP
      WRITE(4,9425)
 9425 FORMAT(' INPUT XMAX: (F16.8)')
      READ(4,*) XMAX
      WRITE(4,9427)
 9427 FORMAT(' INPUT YMIN: (F16.8)')
      READ(4,*) YMIN
      WRITE(4,9426)
 9426 FORMAT(' INPUT YSTEP: (F16.8)')
      READ(4,*) YSTEP
      WRITE(4,9429)
 9429 FORMAT(' INPUT YMAX: (F16.8)')
```

```
      READ(4,*) YMAX
      CALL EXCMS('CLRSCRN')
      WRITE(4,9330)
 9330 FORMAT(' HOW MANY TICKS PER X-AXIS STEP? (I2)')
      READ(4,*) ITICKX
      CALL XTICKS(ITICKX)
      WRITE(4,9331)
 9331 FORMAT(' HOW MANY TICKS PER Y-AXIS STEP? (I2)')
      READ(4,*) ITICKY
      CALL YTICKS(ITICKY)
      IF(XSTEP.EQ.0.0) XSTEP=(XMAX-XMIN)/AX
      IF(YSTEP.EQ.0.0) YSTEP=(YMAX-YMIN)/AY
      CALL GRAF(XMIN,XSTEP,XMAX,YMIN,YSTEP,YMAX)
      CALL YNONUM
      CALL YGRAXS(YMIN,YSTEP,YMAX,AY,' $',-100,AX,0.0)
      CALL RESET ('YNONUM')
      CALL XNONUM
      CALL XGRAXS(XMIN,XSTEP,XMAX,AX,' $',-100,0.0,AY)
      CALL RESET ('XNONUM')
C
C       CURVE PLOTTING
C
      CALL LINESP(1.8)
      CALL SPLINE
      CALL THKCRV(0.02)
      CALL GRACE (0.00)
C
C               DRAW A CONNECTED CURVE
C
C   MULTIPLE CURVE RETURN POINT
 2000 CONTINUE
      CALL EXCMS('CLRSCRN')
      WRITE(4,9445)
 9445 FORMAT(' YOU HAVE A CHOICE OF LINE TYPE:',/,
     +        '   1 ------------- SOLID LINE',/,
     +        '   2 ------------- DOTTED LINE',/,
     +        '   3 ------------- DASHED LINE',/,
     +        '   4 ------------- CHAIN DOT LINE',/,
     +        '   5 ------------- CHAIN DASH LINE',/,
     +        ' PLEASE INPUT LINE TYPE NUMBER: (I1)',/)
      READ(4,*) ICT
      IF(ICT.EQ.2) CALL DOT
      IF(ICT.EQ.3) CALL DASH
      IF(ICT.EQ.4) CALL CHNDOT
      IF(ICT.EQ.5) CALL CHNDSH
      CALL EXCMS('CLRSCRN')
C
C          DATA INPUT FROM EXTERNAL DATA FILE
C
      WRITE(4,9455)
 9455 FORMAT(' INPUT THE FILE DATA SET NUMBER (I2)')
      READ(4,*) INN
```

```
      NUCOLS = 2
      IN=0
      DO 2400 II=1,5000
          READ(INN,9460) (YX(II,JJ),JJ=1,NUCOLS)
 9460     FORMAT(4X,F8.3,2X,F20.18)
          IF((YX(II,1) .LE. 0.0).AND.(II.GT.2)) GO TO 8000
          IN=IN+1
 2400 CONTINUE
 8000 CONTINUE
      ICOL = 2
      DO 8010 II=1,IN
      X(II)=YX(II,1)
      Y(II)=YX(II,ICOL)
 8010 CONTINUE
      REWIND INN
C
C         TERMINATE DATA READING & PLOT CURVE
C
      CALL CURVE(X,Y,IN,0)
C
C         RESET LINE TYPE
C
      IF(ICT.EQ.2) CALL RESET('DOT')
      IF(ICT.EQ.3) CALL RESET('DASH')
      IF(ICT.EQ.4) CALL RESET('CHNDOT')
      IF(ICT.EQ.5) CALL RESET('CHNDSH')
      CALL EXCMS('CLRSCRN')
      WRITE(4,9473)
 9473 FORMAT(' DO YOU WISH TO TERMINATE THIS SUBPLOT?')
      READ(4,9400) ANS
      IF(ANS.NE.YES)  GO TO 2000
C
C            END OF PLOT
C          WRITE ADDITIONAL LABELS
C
      CALL ENDGR(0)
      CALL AREA2D(AX,AY)
      CALL EXCMS('CLRSCRN')
      WRITE(4,9480)
9480  FORMAT(' DO YOU WANT ADDITIONAL LABELS ?',/)
      READ(4,9400) ANS
      IF(ANS.EQ.'N') GO TO 9900
      WRITE(4,9483)
9483  FORMAT(' YOU HAVE A CHOICE OF FUNCTION :',/,
     +      '        1------- GAUSSIAN FUNCTION',/,
     +      '        2------- LEVEL FUNCTION',/,
     +      '        6------- TRAPEZOIDAL FUNCTION',/,
     +      '    INPUT THE NUMBER OF FUNCTION TYPE (I1) :',/)
      READ (4,9401) NF
      IF (NF.EQ.1) THEN
        INF= 'GAUSSIAN FUNCTIONS$'
        WRITE (4,9484)
```

```
9484    FORMAT('SPECIFY BUNCH LENGTH (F4.2):',/,
     +          '       1 ----- 0.24 CM ',/,
     +          '       2 ----- 0.88 CM ',/,
     +          '       3 ----- 1.20 CM ',/,
     +          '       4 ----- 1.76 CM ',/,
     +          '       5 ----- 2.40 CM ',/,
     +          '       6 ----- 2.63 CM ',/,
     +          '       7 ----- 3.50 CM ',/,
     +          '       8 ----- 4.38 CM ',/,
     +             'INPUT THE NUMBER(I1):___',/)
          READ(4,9401) NBL
          IF (NBL.EQ.1) THEN
             IBL= 'BL = 0.24 +CM!$'
          ELSEIF(NBL.EQ.2) THEN
             IBL= 'BL = 0.88 +CM!$'
          ELSEIF(NBL.EQ.3) THEN
             IBL= 'BL = 1.20 +CM!$'
          ELSEIF(NBL.EQ.4) THEN
             IBL= 'BL = 1.76 +CM!$'
          ELSEIF(NBL.EQ.5) THEN
             IBL= 'BL = 2.40 +CM!$'
          ELSEIF(NBL.EQ.6) THEN
             IBL= 'BL = 2.63 +CM!$'
          ELSEIF(NBL.EQ.7) THEN
             IBL= 'BL = 3.50 +CM!$'
          ELSE
             IBL= 'BL = 4.38 +CM!$'
          ENDIF
        ELSEIF(NF.EQ.2) THEN
          INF= 'LEVEL FUNCTION$'
          WRITE(4,9486)
9486    FORMAT('SPECIFY LEVEL FUNCTION LENGTH (F4.2):',/,
     +          '       1 ----- 1.00 CM ',/,
     +          '       2 ----- 3.00 CM ',/,
     +          '       3 ----- 4.50 CM ',/,
     +          '       4 ----- 5.00 CM ',/,
     +          '       5 ----- 6.00 CM ',/,
     +          '       6 ----- 7.00 CM ',/,
     +          '       7 ----- 8.00 CM ',/,
     +          '       8 ----- 9.00 CM ',/,
     +             'INPUT THE NUMBER(I1):___',/)
          READ(4,9401) LF
          IF (LF.EQ.1) THEN
             LFL= 'LFL = 1.00 +CM!$'
          ELSEIF(LF.EQ.2) THEN
             LFL= 'LFL = 3.00 +CM!$'
          ELSEIF(LF.EQ.3) THEN
             LFL= 'LFL = 4.50 +CM!$'
          ELSEIF(LF.EQ.4) THEN
             LFL= 'LFL = 5.00 +CM!$'
          ELSEIF(LF.EQ.5) THEN
             LFL= 'LFL = 6.00 +CM!$'
```

```
        ELSEIF(LF.EQ.6) THEN
           LFL= 'LFL = 7.00 +CM!$'
        ELSEIF(LF.EQ.7) THEN
           LFL= 'LFL = 8.00 +CM!$'
        ELSE
           LFL= 'LFL = 9.00 +CM!$'
        ENDIF
      ELSEIF(NF.EQ.6) THEN
        INF= 'TRAPEZOIDAL FUNCTION$'
        WRITE(4,9501)
9501    FORMAT('SPECIFY TOP LEVEL LENGTH :',/,
     +         '          1 ---- 0.07 CM ',/,
     +         '          2 ---- 2.94 CM ',/,
     +         '          3 ---- 3.185 CM ',/,
     +         '          4 ---- 4.0 CM ',/,
     +         '          5 ---- 5.0 CM ',/,
     +         '          6 ---- 5.04 CM ',/,
     +         '          7 ---- 8.96 CM ',/,
     +         '  INPUT THE NUMBER (I1):___ ',/)
        READ(4,9401) TLL
        IF (TLL.EQ.1) THEN
          ITLL= 'TFTL = 0.07 +CM!$'
        ELSEIF (TLL.EQ.2) THEN
          ITLL= 'TFTL = 2.94 +CM!$'
        ELSEIF (TLL.EQ.3) THEN
          ITLL= 'TFTL = 3.185 +CM!$'
        ELSEIF(TLL.EQ.4) THEN
          ITLL= 'TFTL = 4.0 +CM!$'
        ELSEIF(TLL.EQ.5) THEN
          ITLL= 'TFTL = 5.0 +CM!$'
        ELSEIF(TLL.EQ.6) THEN
          ITLL= 'TFTL = 5.04 +CM!$'
        ELSE
          ITLL= 'TFTL = 8.96 +CM!$'
        ENDIF
        WRITE(4,9502)
9502    FORMAT('SPECIFY BASE LENGTH :',/,
     +         '          1 ---- 5.215 CM ',/,
     +         '          2 ---- 7.0 CM ',/,
     +         '          3 ---- 8.0 CM ',/,
     +         '          4 ---- 8.96 CM ',/,
     +         '  INPUT THE NUMBER (I1):___ ',/)
        READ(4,9401) BL
        IF (BL.EQ.1) THEN
          IBL= 'TFBL = 5.215 +CM!$'
        ELSEIF(BL.EQ.2) THEN
          IBL= 'TFBL = 7.0 +CM!$'
        ELSEIF(BL.EQ.3) THEN
          IBL= 'TFBL = 8.0 +CM!$'
        ELSE
          IBL= 'TFTL = 8.96 +CM!$'
        ENDIF
```

```
      ENDIF
      WRITE(4,9485)
9485  FORMAT(' SPECIFY RADIATION MODE (I1):',//,
     +       '             1---- CERENKOV',/,
     +       '             2 --- SUB-CERENKOV',/,
     +       ' INPUT THE NUMBER:___',/)
      READ(4,9401) NMOD
      IF(NMOD.EQ.1) THEN
          IMOD = 'C+ERENKOV!$'
      ELSE
          IMOD = '+SUB-!C+ERENKOV!$'
      ENDIF
      WRITE(4,9487)
9487  FORMAT(' SPECIFY ENERGY OR NBETA (I1):',//,
     X       '  FOR E ',/,
     X       '     1 -- E = 2.555 MEV',/,
     X       '  FOR NBETA',/,
     X       '     2 -- NBETA = Ø.99 NM',/,
     X       '     3 -- NBETA = Ø.98 NM',/,
     X       '     4 -- NBETA = Ø.97 NM',/,
     X       '     5 -- NBETA = Ø.96 NM',/,
     X       '     6 -- NBETA = Ø.95 NM',/,
     X       ' INPUT THE NUMBER:___',/)
      READ(4,9401) NB
      IF(NB.EQ.1) THEN
C         INB = '+N!%B! = 1.ØØ$'
          INB = 'E = 2.555 M+E!V$'
      ELSEIF(NB.EQ.2) THEN
          INB = '+N!%B! = Ø.99$'
      ELSEIF(NB.EQ.3) THEN
          INB = '+N!%B! = Ø.98$'
      ELSEIF(NB.EQ.4) THEN
          INB = '+N!%B! = Ø.97$'
      ELSEIF(NB.EQ.5) THEN
          INB = '+N!%B! = Ø.96$'
      ELSE
          INB = '+N!%B! = Ø.95$'
      ENDIF
      CALL EXCMS('CLRSCRN')
      WRITE(4.9488)
9488  FORMAT(' SPECIFY ETA (I1):',//,
     X       '            1 -- ETA = 12 ',/,
     X       '            2 -- ETA = 24 ',/,
     X       '            3 -- ETA = 37 ',/,
     X       '            4 -- ETA = 74 ',/,
     X       '   INPUT THE NUMBER:___ ',/)
      READ(4,9401) NETA
      IF(NETA.EQ.1) THEN
        IETA = '%C! = 12 $'
      ELSEIF(NETA.EQ.2) THEN
        IETA = '%C! = 24 $'
      ELSEIF(NETA.EQ.3) THEN
```

```
        IETA = '%C! = 37 $'
      ELSE
        IETA = '%C! = 74 $'
      ENDIF
      WRITE(4,9490)
9490  FORMAT(' SPECIFY BEAM PATH LENGTH (I1):',//,
     X       '          1 -- L = 21 CM (ETA=12,N=6)',/,
     X       '          2 -- L = 42 CM (ETA=12,N=3)',/,
     X       '          3 -- L = 64.8 CM (ETA=37,N=6)',/,
     X       '          4 -- L = 126.2 CM (ETA=12,N=1)',/,
     X       '          5 -- L = 129.5 CM (ETA=37,N=3)',/,
     X       '      INPUT THE NUMBER:___ ',/)
      READ(4,9401) NL
      IF(NL.EQ.1) THEN
        INL = 'L = 21 +CM!$'
      ELSEIF(NL.EQ.2) THEN
        INL = 'L = 42 +CM!$'
      ELSEIF(NL.EQ.3) THEN
        INL = 'L = 64.8 +CM!$'
      ELSEIF(NL.EQ.4) THEN
        INL = 'L = 126.2 +CM!$'
      ELSE
        INL = 'L = 129.5 +CM!$'
      ENDIF
      WRITE(4,9492)
9492  FORMAT(' SPECIFY WAVE LENGTH (I1):',//,
     X       '          1 -- RAMDA = 10.52 CM (N=1)',/,
     X       '          2 -- RAMDA = 3.50 CM (N=3)',/,
     X       '          3 -- RAMDA = 1.75 CM (N=6)',/,
     X       '      INPUT THE NUMBER:___ ',/)
      READ(4,9401) NRAM
      IF(NRAM.EQ.1) THEN
       IRAM = '%L! = 10.52 +CM!$'
      ELSEIF(NRAM.EQ.2) THEN
       IRAM = '%L! = 3.50 +CM!$'
      ELSE
       IRAM = '%L! = 1.75 +CM!$'
      ENDIF
C
      XMES = 2.880
      YMES = 6.130
      IMESS = IMOD
      CALL MESSAG(IMESS,100,XMES,YMES)
C
      YMES = YMES - 0.250
      IMESS = INB
      CALL MESSAG(IMESS,100,XMES,YMES)
C
      YMES = YMES - 0.250
      IMESS = IETA
      CALL MESSAG(IMESS,100,XMES,YMES)
C
```

```
      YMES = YMES - 0.250
      IMESS = INL
      CALL MESSAG(IMESS,100,XMES,YMES)
C
      YMES = YMES - 0.250
      IMESS = IRAM
      CALL MESSAG(IMESS,100,XMES,YMES)
C
      YMES = YMES - 0.250
      IF(NF.EQ.1) THEN
         IMESS=IBL
      ELSEIF(NF.EQ.2) THEN
         IMESS=LFL
      ELSEIF(NF.EQ.6) THEN
         IMESS= ITLL
         CALL MESSAG(IMESS,100,XMES,YMES)
         YMES = YMES-0.250
         IMESS = IBL
      ENDIF
      CALL MESSAG(IMESS,100,XMES,YMES)
C
      IF(HH.EQ.6) THEN
         XMES = 1.20
      ELSE
         XMES = 1.50
      ENDIF
      YMES = -2.25
      IMESS = INF
      CALL MESSAG(IMESS,100,XMES,YMES)
C
9900  CONTINUE
      CALL EXCMS('CLRSCRN')
      IF(IOUT.EQ.2) THEN
      WRITE(4,9493)
 9493 FORMAT(' <CLEAR>, THEN READY FOR HARD COPY')
      ENDIF
      CALL ENDPL(0)
      WRITE(4,9495)
 9495 FORMAT(' DO YOU WANT TO MAKE ANOTHER FIGURE?',/)
      READ(4,9400) ANS
      IF(ANS.NE.YES)  THEN
        GO TO 9999
      ELSE
      ENDIF
      CALL RESET('ALL')
      GO TO 100

 9999 CONTINUE
      CALL DONEPL
      STOP
      END
```

LIST OF REFERENCES

1. **Jelley, J. V.**, *Cerenkov Radiation*, pp. 1–15, Pergamon Press, 1958.

2. **Buskirk, F. R., Neighbours, J. R.**, "Cerenkov Radiation from Periodic Electron Bunches", *Physical Review*, v. 28. pp. 1531–1535. September 1983.

3. **Neighbours, J. R.**, and others, "Cerenkov Radiation from a Finite Length Path in a Gas", *Physical Review*, v. 29, pp. 3246–3252, June 1984.

4. **Maruyama, X. K.**, and others, "Electron Beam Bunch Profile Determination through Cerenkov Radiation", *IEEE Transactions on Nuclear SScience*, v. NS–32, pp. 1994–1996, October 1985.

5. **Neigbours, J. R.**, and others, "Cerenkov and sub–Cerenkov Radiation from a Charged Particle Beam", *J. Appl. Phys.* 61 (8), 15 April 1987.

6. **Vujaklija, M.**, "Cerenkov Radiation from Periodic Electron Bunches for Finite Emission length in Air", Master's Thesis, Naval Postgraduate School, Monterey, Califonia, December 1984.

7. **Turner, E. R.**, "Form Factor Effects on Microwave Cerenkov Radiation", Master's Thesis, Naval Postgraduate School, Monterey, California, December 1984.

8. **Stein, K. M.**, "Effects of Pulse Shaping on Cerenkov Radiation", Master's Thesis, Naval Postgraduate School, Monterey, California, June 1986.

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